United States Coast Guard, First District
Lighthouse Protection Studies, New England

Gay Head Light Station Martha's Vineyard, Massachusetts

US Army Corps
of Engineers
New England Division

UNITED STATES COAST GUARD, FIRST DISTRICT

LIGHTHOUSE PROTECTION STUDIES, NEW ENGLAND

GAY HEAD LIGHT STATION
MARTHA'S VINEYARD, MASSACHUSETTS

AUGUST 1989

U.S. ARMY CORPS
OF ENGINEERS

NEW ENGLAND DIVISION

GAY HEAD LIGHT STATION, MARTHA'S VINEYARD, MA
EROSION STUDY

EXECUTIVE SUMMARY

The U.S. Coast Guard is concerned about erosion problems which are threatening six of their lighthouses in New England. Under a memorandum of understanding (MOU), the Corps has agreed to study these six lighthouses and make recommendations to the Coast Guard regarding the best method(s) of protecting the structures. Gay Head Light on Martha's Vineyard is the subject of this report.

Gay Head Light overlooks the ocean from a high cliff site on the island of Martha's Vineyard, Massachusetts. The island is composed primarily of glacial unconsolidated sediments. Gay Head cliffs consist of a highly complex series of reworked glacial material including a significant amount of clay. The cliffs, eroded from these unconsolidated sediments, rise to over 140 feet and extend along the shore for approximately 4,000 feet.

The problem addressed in this report is the clear danger presented to the safety and stability of the lighthouse by the well documented and relatively rapid rate of cliff recession occurring in the area. Several common types of cliff erosion as well as periodic landslides cause the cliffs to retreat inland at average rates estimated to range from 1 to 3 feet per year. The presence of clay in the cliffs tend to cause the erosion to be in blocks and incremental rather than smooth and constant. The annual rates are extremely variable. It is common for a given area to have little or no erosion for several years and then to experience catastrophic erosion with large amounts of cliff failure in very short periods of time. One location near the lighthouse lost 19 feet of bluff in a one year span from 1924 - 25 and then experienced no measurable erosion for the next 26 years. Planning in the short to medium time range must take the fragmented incremental nature of the erosion rates into consideration and not simply rely on calculated average annual rates as the basis for future estimates.

The following areas were analyzed in the study to aid in the prediction of future conditions and the selection of alternatives:

Geology
Ecology
Historical Shoreline Changes
Wave Climate
Coastal Processes
Erosion Processes.

At present, the lighthouse is 55 feet from the cliff edge at its closest point. Analyses of survey data for cliff segments directly adjacent to the lighthouse property show those areas to exhibit erosion rates ranging from 1.4 feet per year to 4 feet per year, including at least one catastrophic failure event of 19 feet in one year. If one assumes that the potential for immediate failure of bluff at the light becomes critical when only 20 feet of land separates the lighthouse from the cliff edge, (based on the 19 foot in one year failure referred to above), then the maximum and minimum life expectancy of the lighthouse at its present location ranges from 25 years at

1.4 feet per year to 9 years at 4 feet per year. While these projections are only estimates based on past erosional history determined from survey records, it is nevertheless very clear that the Gay Head Lighthouse is in danger, and very possibly imminent danger, of being lost to erosion unless some plan of action is adopted to save it.

Several alternative plans designed to protect and/or prolong the life of the structure are discussed in this report. Cost estimates for most of these alternatives have been provided. A summary comparison of these alternatives and their costs is presented as Table 6 in the body of the report. Because of the length of beach and cliff face needing protection, the costs of most solutions are prohibitive.

The continued erosion of the cliffs cause a constant renewal and freshening of the cliff face which allows the clays and other sediments to exhibit an extraordinary display of colorful and beautiful scenery which has attracted sufficient attention to warrant their being designated a Registered National Monument. Any attempts to cover the cliff face or substantially reduce the "cleansing" effect of erosion there will most probably be met with solid opposition from a variety of groups intent on preserving the world famous natural beauty of the Gay Head cliffs.

The analysis of future conditions at Gay Head discussed in the body of this report concluded that there is a clear possibility of imminent loss of the lighthouse due to cliff failure. Accordingly some course of action should be adopted in the very near future. This report recommends that the lighthouse either be moved inland or a new structure be constructed at a safe site removed from the cliff edge. These two choices are by far the most economical of all the alternatives considered. The moving or new construction of the structure would also not seriously impact the natural erosion and resulting renewal of the beauty of the cliffs which is one of the areas greatest assets.

GAY HEAD LIGHT STATION, MARTHA'S VINEYARD, MA
EROSION STUDY

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INTRODUCTION

This report is the culmination of a study performed under a Memorandum of Understanding (MOU) between the U. S. Coast Guard and the U. S. Army Corps of Engineers. Gay Head Light Station is the second of six lighthouses to be investigated under this MOU. The severe erosion occurring at the lighthouse threatens to destroy this historically significant structure. The Coast Guard requested that the Corps study the situation and report upon the following items:

- natural setting
- historical analysis of shoreline changes
- wave climate and coastal processes
- erosion processes and critical areas
- a monitoring survey program
- predicting future conditions
- plan formulation and evaluation
- findings and recommendations.

NATURAL SETTING

LOCATION

The Gay Head Cliffs are found at the northerly part of the western end of Martha's Vineyard, an island located 3 miles south of Cape Cod Massachusetts (see map, Plate 1). The island is approximately 18 miles long in an east-west direction and averages about 9 miles in width in a north-south direction. It is composed predominately of glacial sediments overlying older Cretaceous and Tertiary coastal plain sediments. The island faces Vineyard Sound to the north, Nantucket Sound to the east, the Atlantic Ocean to the south and southwest and Block Island Sound further west.

GEOLOGY

The surficial geology of Martha's Vineyard consists of a broad band of till deposits along the northwest and northeast sides of the Island. These deposits surround, in the central and southern part of the Island, widespread outwash deposits of interbedded sands and gravels. The island is roughly in the shape of a triangle with the northeast and northwest sides made of till and the middle of the area and its southern side composed of outwash.

The till was deposited over Cretaceous and Tertiary coastal plain sediments and earlier glacial sequences as a lobate linear terminal moraine from the most recent advance of Pleistocene ice over the area. During melting and retreat of the ice front, meltwater streams carried much of the glacial sediments south and deposited them as the stratified drift in front (generally southerly) of the ice front. More recent wind and wave action has shaped the shores of the island into its present configuration.

A more detailed look at the Gay Head area, site of the subject lighthouse, reveals a very complex series of contorted glacial and preglacial sediments which are rich in clay and other fine sediments. It is these

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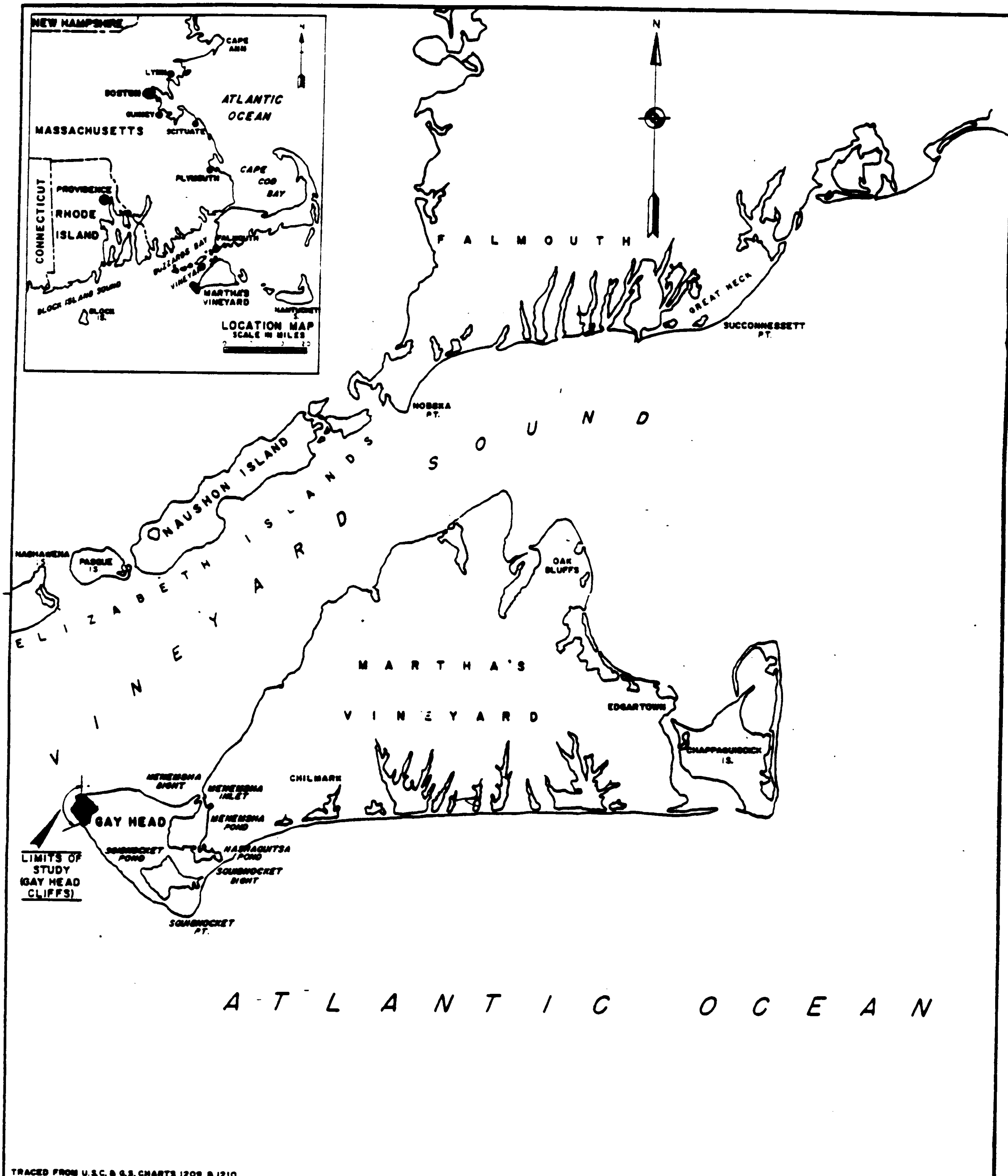

PLATE 1

distorted beds of clay and silt with interbedded sands and gravels which outcrop to form the Gay Head cliffs. The continued erosion of the cliff face reveals several lithologies of clay and other sediments which are multi-colored and produce the spectacular scenery visible at the cliffs.

The glacial sediments at Gay Head have been recently mapped (Oldale and Barlow, 1986) as Gay Head moraine deposits consisting of displaced strata of Cretaceous, Tertiary and Pleistocene age, till and boulders. Overlying the Gay Head Moraine deposits are tills of the Martha's Vineyard moraine. The pre-glacial Cretaceous and Tertiary sediments consisted predominantly of sands and clays.

During the 2 million year extent of the Pleistocene Epoch, several advances and retreats of the glacial ice occurred. Each period of glaciation eroded, moved and redeposited the former sediments resulting in increasing complexity of the sequence. The structural reworking of the pre-existing sediments, the deposition of additional material brought down by each new advance of ice, and the further reworking and deposition during interglacial periods resulted in a sequence of sediments extremely complex in their stratigraphic and structural relationships. Shaler (1890) describes the strike of these folded and tilted beds as generally NW to SE in direction with some significant variation in compass direction. This orientation can be interpreted to mean that the beds extend inland in a direction very generally normal to the cliff's edge.

The sediments in the cliff area consist of gravel, sand, cobbles (including large boulders), silt and clay with some minor layers of peat and lignite. The texture and composition vary significantly. Clay is a major constituent and often clay layers are found to create impermeable surfaces above and below layers of sand and gravel. This complex structure of interbedded and folded sands and clay layers results in very complicated erosional patterns. The iron staining and precipitate, very commonly observed, is indicative of abundant water movement within and on the cliffs. Most probably the water infiltrates and percolates through the more permeable sandy layers and emerges at the cliff face upon meeting an impermeable layer such as clay or silt. This movement of water commonly results in springs, perched water tables, piping and other forms of sapping and seepage. This situation is extremely conducive to erosion of the cliffs and most certainly accounts for a significant part of the ongoing cliff retreat which averages 1 to 3 feet per year with significant local variation.

SITE DESCRIPTION

Gay Head Light stands 140 feet above sea level on top of the Gay Head Cliffs. The lighthouse is quite near the edge of the cliff with only 55 feet separating the structure from the cliff scarp at the narrowest point. (See Photo 1.) The lighthouse is red brick and was built, in 1856. The Coast Guard owns and maintains the light structure and land.

Gay Head's 770,000 candle power light is visible 20 miles at sea, according to a wooden sign near the structure. It warns mariners of the coast and also of Devils Bridge bar, a shoal area composed of sediments worn from the cliff, which extends about 1 mile northwest from Gay Head and can trap unwary ships. Ships coming up Vineyard Sound at night can find their

PHOTO 1
LOCATION OF STRUCTURE NEAR EDGE OF CLIFF

way using Gay Head Light on the starboard side and Cuttyhunk Light on the port side. Gay Head Light's signal is 3 white flashes followed by 1 red flash over a 40 second interval.

The cliffs rise to over 140 feet and extend along about 4,000 feet of shoreline. The land at the top of the cliff slopes gently easterly so that the cliff edge is the highest elevation in the area.

Erosion and landslide activity are causing the cliffs to recede inland at variable rates estimated from one foot to more than four feet per year. At its present location of 55 feet from the cliff edge, the lighthouse is clearly in danger of falling into the sea unless some mitigating action is taken in the near future.

The constant erosion of the cliff face has exposed tilted and folded clay and sand strata that exhibit spectacularly vivid and contrasting colors. Gay Head's scenic beauty attracts many tourists. The area has been designated as a Registered National Monument. Visitors to the light admire the cliffs from an overlook on the north side of the lighthouse property. The overlook offers splendid views of the cliffs to the north. Within recent years climbing of the cliffs has been banned and signs prohibiting such activity are prominently displayed.

HYDROLOGY

The tides in the area are semi-diurnal with a mean range of 2.9 feet and a spring range of 3.5 feet.

The cliffs face to the west and thus escape the brunt of easterly and northeasterly storms. The waves that produce the most local erosion rise from the frequent southeast through southwesterly storms that occur in the area. Infrequently hurricanes produce high winds from the south and southwesterly directions. The storms that produce the most damaging waves are commonly of long duration lasting through several tidal cycles. Wind velocity and rainfall produced in such storms are major contributors to the erosion and slope failure ongoing at the cliffs.

HISTORICAL ANALYSIS OF CLIFF RECESSION

Cliff retreat in the Gay Head area is the inevitable result of the natural geologic and coastal processes occurring there. This section of the report will discuss the cliff recession, illustrate both analytically and graphically the rates of retreat, and emphasize the variability of local rates of cliff recession in the area of the Coast Guard Light at Gay Head.

Information on the recession rate of the cliffs was gathered from the following sources:

1. Surveys of the lighthouse plot and surrounding lands provided by local surveyors. These include surveys done in 1886, 1924, 1951, 1976, 1978 and 1985. The 1886 survey also includes data from when it was updated in 1933. The 1924 survey includes updated data from 1925 and 1960.

2. Aerial photographs from 1967 and 1977.

3. <u>These Fragile Outposts</u>, B.B. Chamberlain, 1964

4. <u>A Study of Methods to Preserve Gay Head Cliffs, Martha's Vineyard, Massachusetts</u>, prepared for the Corps of Engineers by Woodward-Moorhouse & Assoc., Inc., 1970

5. <u>Beach Erosion Control Study, Gay Head Cliffs, Martha's Vineyard, Massachusetts</u>, September, 1973, Corps of Engineers

6. Site Visit by Corps Personnel, 1988

Measurements were taken from the lot lines at the back of the plot to the edge of the cliff using the local surveying maps and were also scaled from the aerial photographs. The most complete data sets were for the years 1951, 1967 and 1978. Little data is available for the land south of the lighthouse, and it was not considered a reliable source of information. Therefore, recession rates were developed using only data from the lighthouse lot and the land north of it. The cliff edge position in 1967 was obtained from the aerial photograph of the same year and the edge of cliff for 1951 and 1978 were scaled from the corresponding survey maps. These data, as well as information gained from aerial photographs and landform analyses, were used to construct the Cliff Recession Map plotted as Plate 2.

Discrepancies exist in the Cliff Recession Map (Plate 2), due to variances incurred in the scaling of survey data from maps and aerial photographs. The 1967 cliff edge position was plotted directly from a photogrammetric survey made in the same year. The other lines were plotted from maps obtained from local surveyors on Martha's Vineyard. Although there are inconsistencies in the map, it indicates quite clearly the areas where recession has been proceeding most rapidly over the past two decades.

The recession rate of the Gay Head Cliffs on Martha's Vineyard varies considerably over certain periods of time. The erosion of the cliffs is not a constant process. Rather than recede at a continuous steady rate, the cliffs erode at irregular intervals. Large areas might erode significantly for a few years and then be relatively inactive for many more years. Table 1, "Yearly Cliff Positions", and Table 2, "Average Cliff Recession Rates" well illustrate this erosion pattern.

Table 2 was derived from Table 1 and shows the average rate of recession for each location for those years where data was available. The overall average annual rates of cliff recession, derived from data gained from the sources listed above and presented in Tables 1 and 2, are displayed in Table 3. The same rates are shown graphically in Figures 1 through 4. Figure 1 shows the average annual cliff recession rates for locations A thru J. Figures 2 thru 4 show cliff recession rates for stations G, H, and I which are immediately adjacent to and inclusive of the lighthouse property.

One very probable reason for the variability in the average recession rate is the occasional sudden failure by landslides which occur at irregular intervals. For example, at location E, from 1935 to 1951 the recession rate was 13.1 feet per year. But, from 1951 until 1985 it averaged only 0.6 feet per year. This can probably be attributed to large failures of the slope

TABLE 1

GAY HEAD LIGHTHOUSE

YEARLY EDGE OF CLIFF POSITION (FEET)
MEASURED FROM BACK OF PROPERTY LINE

LOCATION	1870	1880	1886	1924	1925	1933	1935	1951	1960	1967	1976	1977	1978	1985	1988
A								158		134	33		33		
B - CORNER OF REAR BLDG. TO EDGE								183		93		47			
C								191		137	112		112		
D								300		300	280		280		
E							600	390		374			370	370	
F							525	390		378			230	185	
G	325	310	265	243	224			224	222	212			82		56
H - LIGHTHOUSE TO EDGE OF BANK			195	186		186			91	64		55			55
I		340								213			183		
J								666		587			560		

TABLE 2

AVERAGE CLIFF RECESSION RATES FT./YR.

LOCATION	1870		1880		1886		1924		1925		1933		1935		1951		1960		1967		1976		1977		1978		1985		1988
A-															X	1.5			I	11.2	I	0.0			I				
B- NW CORNER OF BLDG. TO EDGE															X	5.6			I	4.6			I						
C-															X	3.4			I	2.8	I	0.0			I				
D-															X	0.0			I	2.2	I	0.0			I				
E-													X	13.1	I	1.0			I	0.4					I	0.0	I		
F-													X	8.4	I	0.8			I	13.5					I	6.4	I		
G-	X	1.5	I	7.5	I	0.6	I	19	I	0.0					I	[illegible].2	I	1.4	I	11.8					I	2.6			I
H- LI HOUSE TO EDGE					X	.2	I	0.0			I	3.5					I	3.9	I	0.9			I	0.0					I
I-			X	1.5															I	2.7					I				
J-															X	4.9			I	2.5					I				

TABLE 3
AVERAGE ANNUAL CLIFF RECESSION RATES IN FEET PER YEAR

Location	Average Annual Recession Rate (feet/year)
A	4.6
B	5.2
C	2.9
D	0.74
E	4.6
F	6.8
G	2.3
H	1.4
I	1.6
J	3.9

Average overall annual recession rate is 3.4 feet/year

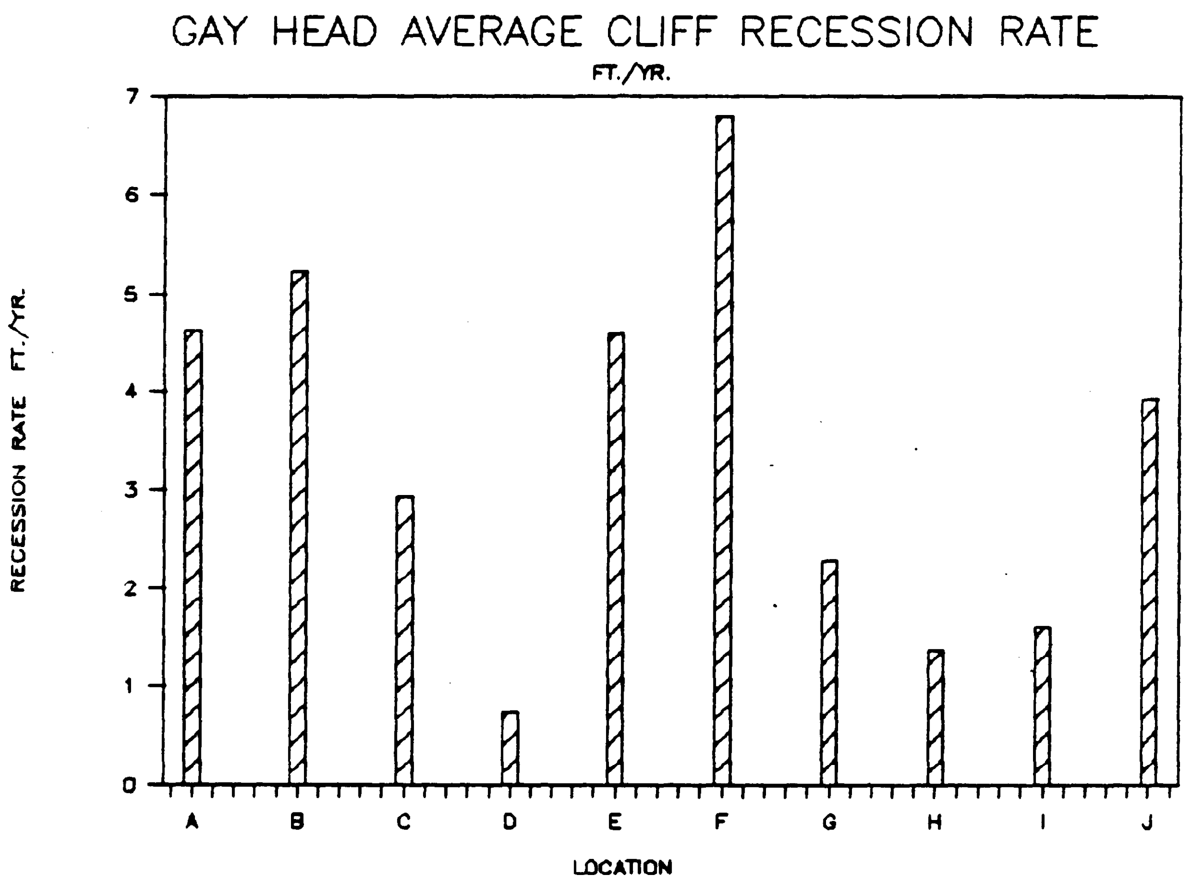
GAY HEAD AVERAGE CLIFF RECESSION RATE
FT./YR.
RECESSION RATE FT./YR.
0
1
2
3
4
5
6
7
A
B
C
D
E
F
G
H
I
J
LOCATION

FIGURE 1

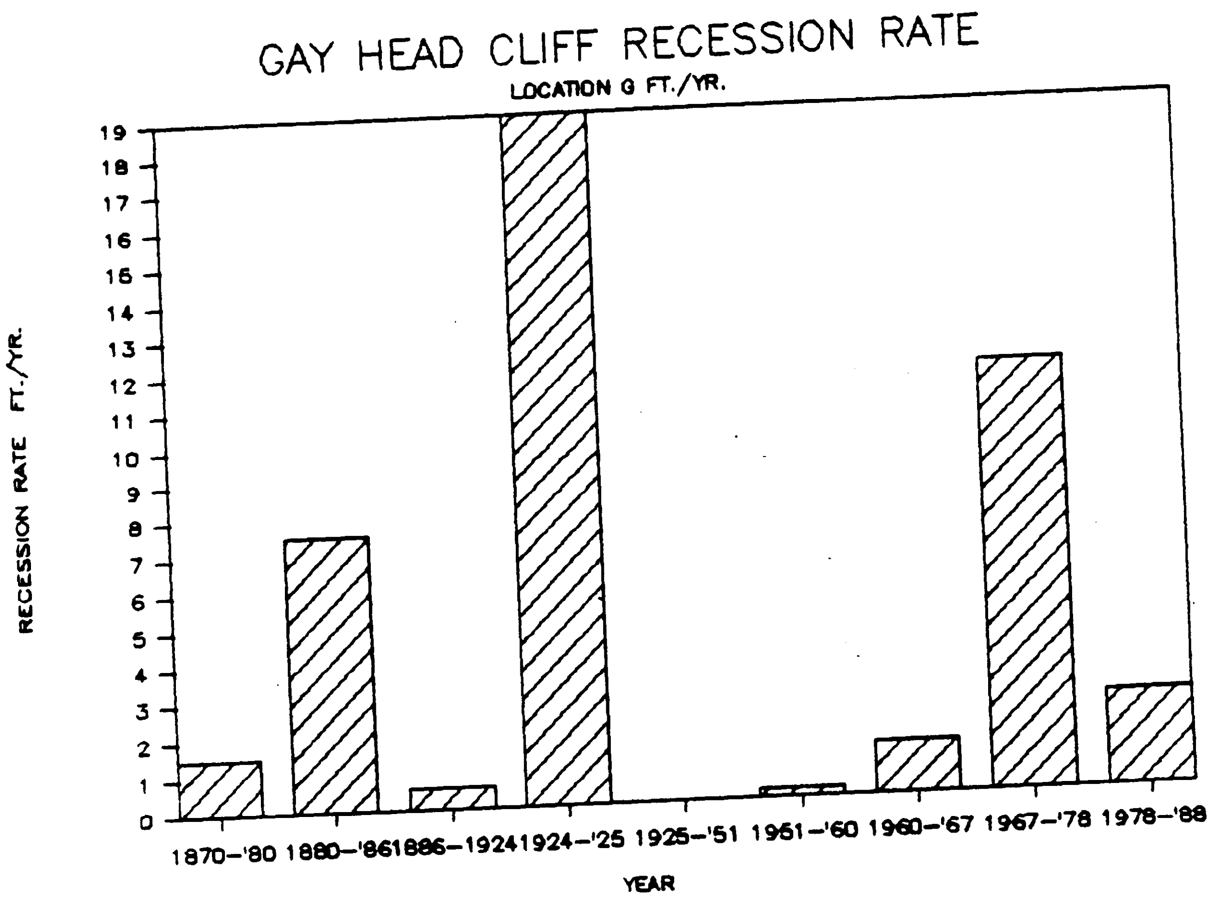
GAY HEAD CLIFF RECESSION RATE
LOCATION G FT./YR.
RECESSION RATE FT./YR.
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1870–'80
1880–'86
1886–1924
1924–'25
1925–'51
1951–'60
1960–'67
1967–'78
1978–'88
YEAR

FIGURE 2

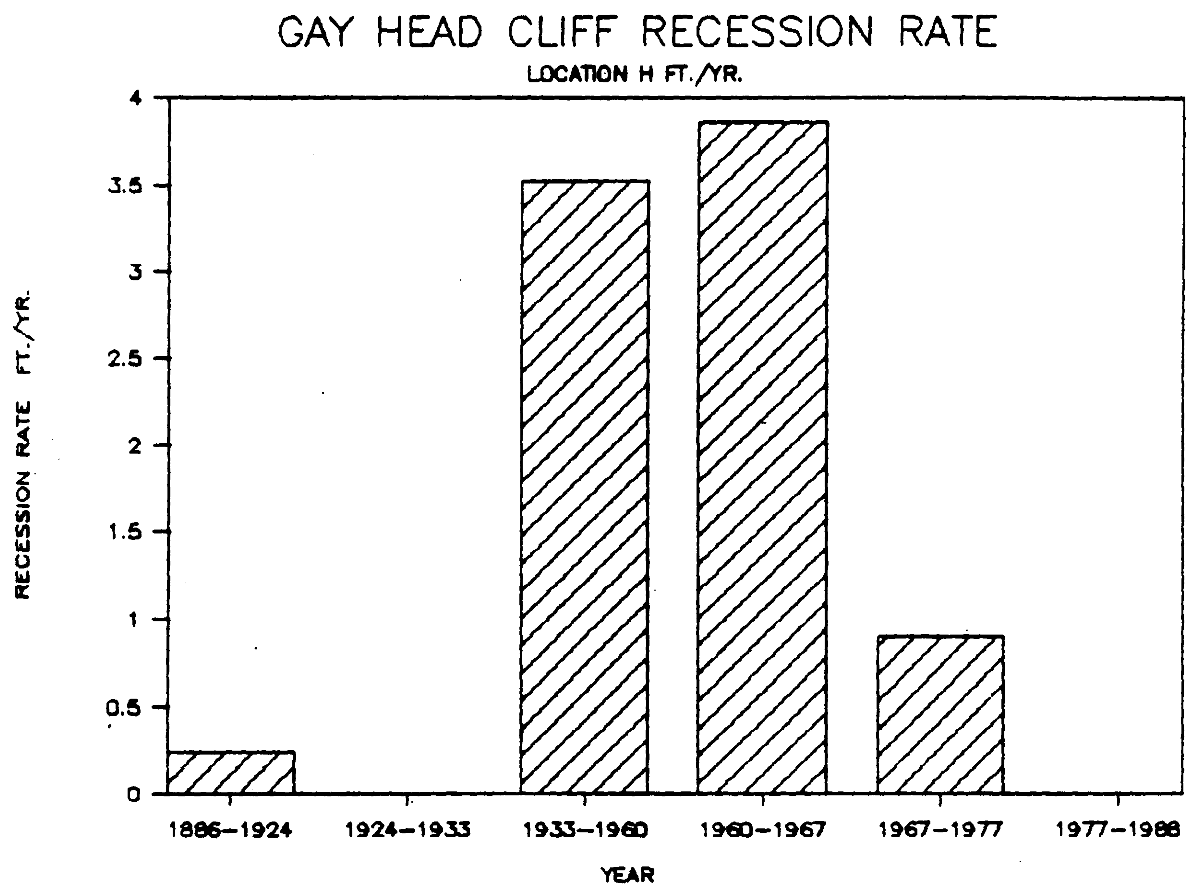
GAY HEAD CLIFF RECESSION RATE
LOCATION H FT./YR.
RECESSION RATE FT./YR.
0
0.5
1
1.5
2
2.5
3
3.5
4
1886–1924
1924–1933
1933–1960
1960–1967
1967–1977
1977–1988
YEAR

FIGURE 3

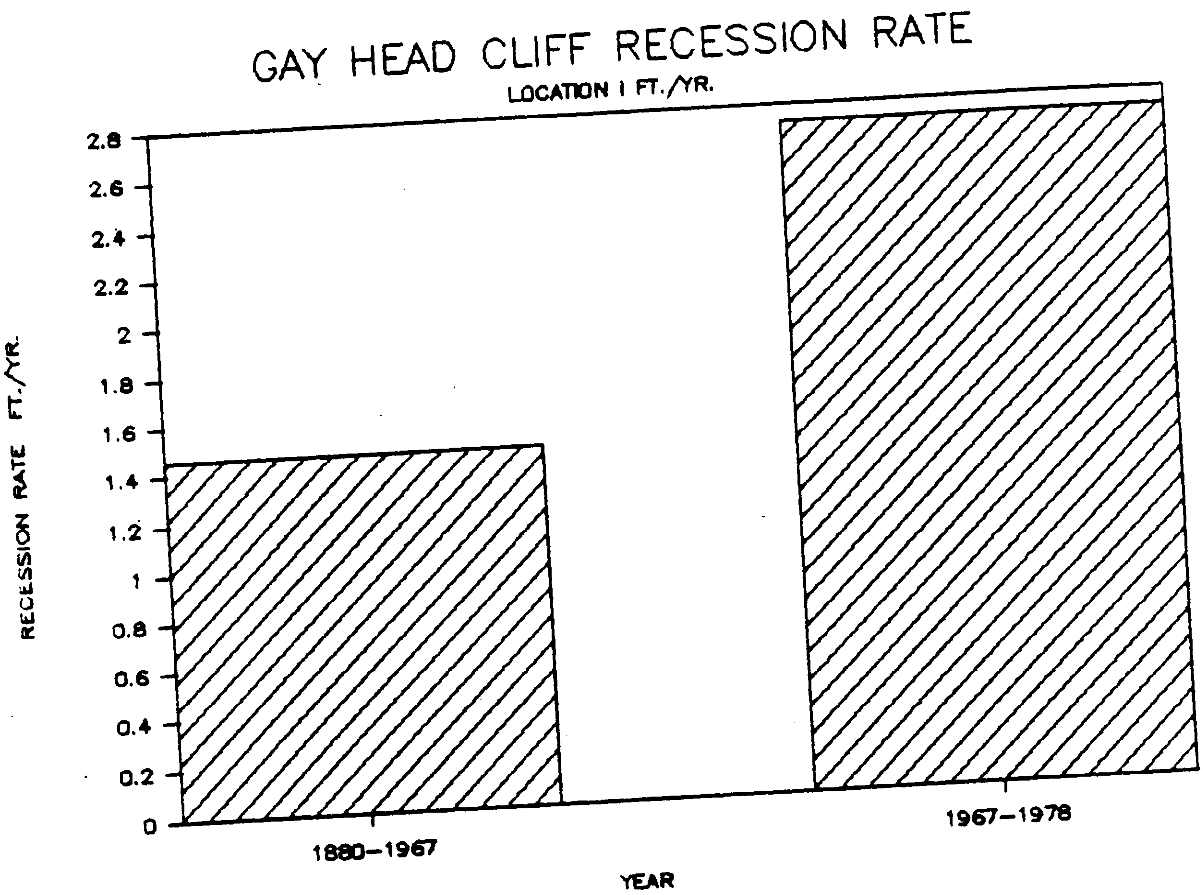
GAY HEAD CLIFF RECESSION RATE
LOCATION I FT./YR.
RECESSION RATE FT./YR.
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
1880–1967
1967–1978
YEAR

FIGURE 4

such as landslides which occur infrequently as compared to a steady rate of erosion. Some of the higher values in Table 2 probably reflect the effects of localized landslides. Another good example of this variability in rates of erosion is the recession rate at location G, the northern property line of the lighthouse lot. Here it varies from 19 ft/yr (1924 to 1925) to 0 ft/yr for the next 26 years (1925 to 1951).

Because cliff erosion rates exhibit significant local variation, average annual recession rates may not be as meaningful as rates for certain selected periods. For purposes of comparison, erosion data for two 16 year periods, 1951-1967 and 1967-1983, is shown on Table 4. For locations with no data for 1983, the most recent data available were extrapolated to 1983 so a comparison could be made between 16 year periods.

The highest rates of recession for the most recent years (1967-1983) have been at locations A, F, and G with relative stability (minimal change or decrease in the recession rate) exhibited at the other locations for this period. It should be noted that location G, H, and I cover the area occupied by the lighthouse. It is also interesting to note that of the ten locations compared, 50% show an increased rate of recession and 50% show a decreased rate. This observation underscores the locally very uneven rates at which the cliffs retreat in this area.

There are four major landslides located on the cliffs and labeled on the Cliff Recession Map. Correlating the recession information with the four landslides reveals the majority of cliff recession has taken place between Landslides I & II and between Landslides III & IV. The actual rate of recession at the cliff averages from 0.7 ft/yr to 6.8 ft/yr for locations D and F, respectively. This difference in recession rates is due to smaller landslides in localized areas of the cliff between the major landslides. Erosion of the cliff at Landslides I & II also seems to be more active than at III & IV. At location H (Landslide IV) the distance from the lighthouse to the edge of the cliff has not changed substantially since 1967. This is evidence that Landslide IV, which is directly west of the lighthouse, seems to be temporarily stable.

In a previous (1970) report on the Gay Head Cliffs prepared by Woodward-Moorhouse & Assoc., Inc., it was stated that the current recession of the cliffs at the backs and sides of the landslides is proceeding as a succession of smaller landslides which remove only a few cubic yards of material each time. The 1970 report also concluded that, "The development of new smaller landslides, especially at the cliff exposures bounding the five massive landslide scars, is a continuing process. It is largely responsible for the continuing, observable, and recorded recession of the cliff edge."

The recent data collected from surveys made in 1976 and 1978, the aerial photos made in 1977, and the field reports in 1988, concur with the above finding; namely that the greatest amount of cliff recession is taking place between the major landslides, specifically at locations A, F, and G as shown on the Cliff Recession Map.

The recession rate specifically at the lighthouse lot varies considerably from a high of 19 ft/yr for 1 year to a low of 0 ft/yr for 26 years. The average cliff recession rates over the time period of collected data for the

TABLE 4

AVERAGE RECESSION RATE FOR SELECTED PERIODS
(FT/YR)

LOCATION	1951-1967	1967-1983
A	1.5	9.2
B	5.6	4.6
C	3.4	2.3
D	0.0	1.8
E	1.0	0.3
F	0.8	11.3
G	0.8	8.9
H	3.7	0.6
I	1.3	2.7
J	4.9	2.5

three locations closest to the lighthouse (G, H, and I) are 2.3, 1.4, and 1.6 ft/yr, respectively. Also, it is clear, from looking at the Cliff Recession Map (Plate 2), that very active erosion of the cliffs is occurring to the northwest of the lighthouse.

The following is a list of average recession rates determined in previous studies:

These Fragile Outposts : B.B. Chamberlain, 1964	1 - 2 ft/yr
Woodward-Moorhouse Report, 1970 :	1 ft/yr
J.N. Hutchinson, 1970 :	1 - 2 ft/yr
Beach Erosion Control Study : Corps of Engineers, 1973	1 - 2 ft/yr

The average annual rate of cliff recession as determined in this report and shown in Table 3 is 3.4 feet per year. Therefore, the average rate of recession for the Gay Head Cliffs at the lighthouse as determined from several studies can, with confidence, be stated to be in the range of 1-3 feet per year. This average rate includes sporadic localized failures which have in the past eroded the cliff as much as 19 feet in one year. The 3.4 feet per year calculated in this report, while generally consistent with the other figures noted, is slightly higher. The difference may be due to the larger base of data (surveys, photographs, site visits) used in this report.

WAVE CLIMATE AND COASTAL PROCESSES

The Coastal Engineering Research Center (CERC) has developed Sea State Engineering Analysis System (SEAS) which is a data base containing the sea conditions along the U. S. coast at 3 hour intervals for the years 1956-1975. The data was hindcast using actual meteorological conditions for the time period. Atmospheric pressure differences were used to generate wind speed at a 19.5 meter elevation. Wind speed was then used by a numerical model to simulate wave generation. Available data includes significant wave height, peak spectral period, and wave direction. There were three phases to the SEAS study. Each phase brought waves closer to the shoreline. Phase II, used for the Gay Head Light study, took data for deep water waves and refined it to better reflect the sheltering effects of the continental shelf geometry. The SEAS station location closest to Gay Head Lighthouse is at 71.30 degrees west longitude and 40.94 degrees north latitude. This is about 36 nautical miles from Gay Head Light in a southwesterly direction.

Various tables are available from the SEAS data set. Figure 5 is typical output. It contains the percent occurrence of waves of given heights, periods and directions.

For each direction, SEAS calculates the percent of the waves coming from that direction, average significant wave height, maximum significant wave height and average peak spectral period over the twenty year period. Although these data are for a location 36 nautical miles from Gay Head Light, the wave characteristics of storm waves at Gay Head Light should be generally similar.

FIGURE 5 - TYPICAL SEAS DATA

PERCENT OCCURRENCE (X1000) OF HEIGHT AND PERIOD BY DIRECTION
22.5 DEGREES ABOUT 90.0 DEGREES AZIMUTH

STATION: A2019 40.94N/ 71.30W

NO. CASES: 3782
% OF TOTAL: 6.5

HEIGHT IN METERS	PEAK PERIOD (IN SECONDS) 0.0-2.9	3.0-4.9	5.0-6.9	7.0-8.9	9.0-10.9	11.0-12.9	13.0-14.9	15.0-16.9	17.0-18.	19.0 LONGER	TOTAL
0.0-0.9	126	860	116	1221	147	227	75	.	.	.	2772
1.0-1.9	.	179	559	665	242	434	171	.	.	.	2250
2.0-2.9	.	.	150	405	73	155	104	.	.	.	887
3.0-3.9	.	.	27	284	23	65	46	.	.	.	445
4.0-4.9	.	.	.	39	10	18	.	.	.	.	67
5.0-5.9	.	.	.	.	13	3	8	.	.	.	24
6.0-6.9	.	.	.	.	.	1	6	.	.	.	7
7.0-7.9	.	.	.	.	1	1	.	.	.	.	2
8.0-8.9	.	.	.	.	.	.	.	.	.	.	0
9.0-9.9	.	.	.	.	.	.	.	.	.	.	0
10.0+	.	.	.	.	.	.	.	.	.	.	0
TOTAL	126	1039	852	2614	509	904	410	0	0	0	

MEAN HS(M) = 1.4 LARGEST HS(M) = 7.3 MEAN TP(SEC)

Table 5 is a summary of the available (1956-1975) wave data for the SEAS location closest to Gay Head Lighthouse. It shows the most common waves to be from the south and south-southwest. These are usually fair weather waves since the average wave size from these directions is fairly small. Waves from the west are more common than waves from the east since the prevailing onshore wind is from the west. Since Gay Head Lighthouse is exposed to the ocean only on the western side, waves from the east have no effect in the area. In general, the times when the waves are from the east at the SEAS site are periods on relative calm at the Gay Head Lighthouse. The largest storm waves come from the south and southwest which is to be expected since this direction has the largest fetch.

A wave refraction analysis of the Gay Head Lighthouse area was done using RCPWAVE. RCPWAVE is a computer program which solves Berkhoff's mild slope equation using an iterative finite difference scheme. It calculates refraction and diffraction effects, assuming linear waves. The program does not include energy dissipation except in the surf zone where it is introduced when the waves break. RCPWAVE was developed by the U. S. Army Corps of Engineers Coastal Engineering Research Center (CERC) and is described in CERC Technical Report 86-4.

RCPWAVE requires bathymetry data, deep water wave height, wave period, and deep water wave direction as input. The bathymetry data was obtained from nautical chart number 13233 (1975 edition). Depths were found at equally spaced points for a distance of 3.8 statute miles in the longshore direction and 4.5 miles in the offshore direction. A total of 288 depths were determined from the chart.

Using RCPWAVE data, waves from different directions were used in an analysis of wave angles as they approach the shore. Figures 6 and 7, plot the angle the waves make with the shore at grid points. This is not a ray trace, it shows wave angle but not areas of energy concentration. Data for these plots were generated by RCPWAVE and plotted by hand. Because of the variability of the bottom topography and the lack of complete data, the results are not definitive. However it is clear in all plots that wave angles are refracted near the area of the lighthouse. Although no data for energy concentration was available, it is reasonable to infer that the patterns of wave refraction noted are indicative of areas of energy concentration at the base of the cliffs near the Gay Head Lighthouse. As such they underscore the vulnerability of the cliffs to wave undercutting and recession in the vicinity of the lighthouse.

The longshore transport just at the north end of the cliffs at Gay Head is mapped by the U.S.G.S. (Kaye, 1973), as easterly. This analysis is confirmed by accounts of residents who observe the 'red water' (from eroded red clays from the cliffs; see Photo 2) moving north and east from the cliffs. A significant amount of the material removed from the cliffs is evidently transported easterly along the shoreline north of Lobsterville (a village located along the north shore of the area about two miles east of the lighthouse) because that area is mapped (Kaye, 1973, Oldale 1986) as undergoing accretion. The SEAS data in Table 5 shows that both the largest percentage of waves, as well as the highest waves, rise from the southwesterly direction. As these waves refract around the north edge of the cliffs they will transport sediment easterly where it will accrete as described above.

TABLE 5

GAY HEAD LIGHT SEAS DATA

		%	hs(ave)	hs(large)	tp
			METERS		SEC
0.0	N	3	1.2	4.7	4.4
22.5	NNE	3	1.2	4.9	4.4
45.0	NE	2	1.3	6.1	4.4
6[illegible]5	ENE	3	1.6	8.9	5.4
[illegible]0	E	6	1.4	7.3	7.5
11[illegible]5	ESE	2	1.4	6.9	4.7
135.0	SE	7	1.0	6.1	6.4
157.5	SSE	3	1.2	7.5	4.5
180.0	S	12	1.0	8.0	6.6
202.5	SSW	15	1.1	9.3	6.1
225.0	SW	8	1.3	9.9	4.9
247.5	WSW	5	1.3	9.7	4.4
270.0	W	6	1.6	7.4	4.8
292.5	WNW	6	1.7	5.8	5.0
315.0	NW	7	1.4	4.7	4.7
337.5	NNW	5	1.3	6.1	4.5

FIGURE 6

RCPWAVE WAVE ANGLES FROM WEST

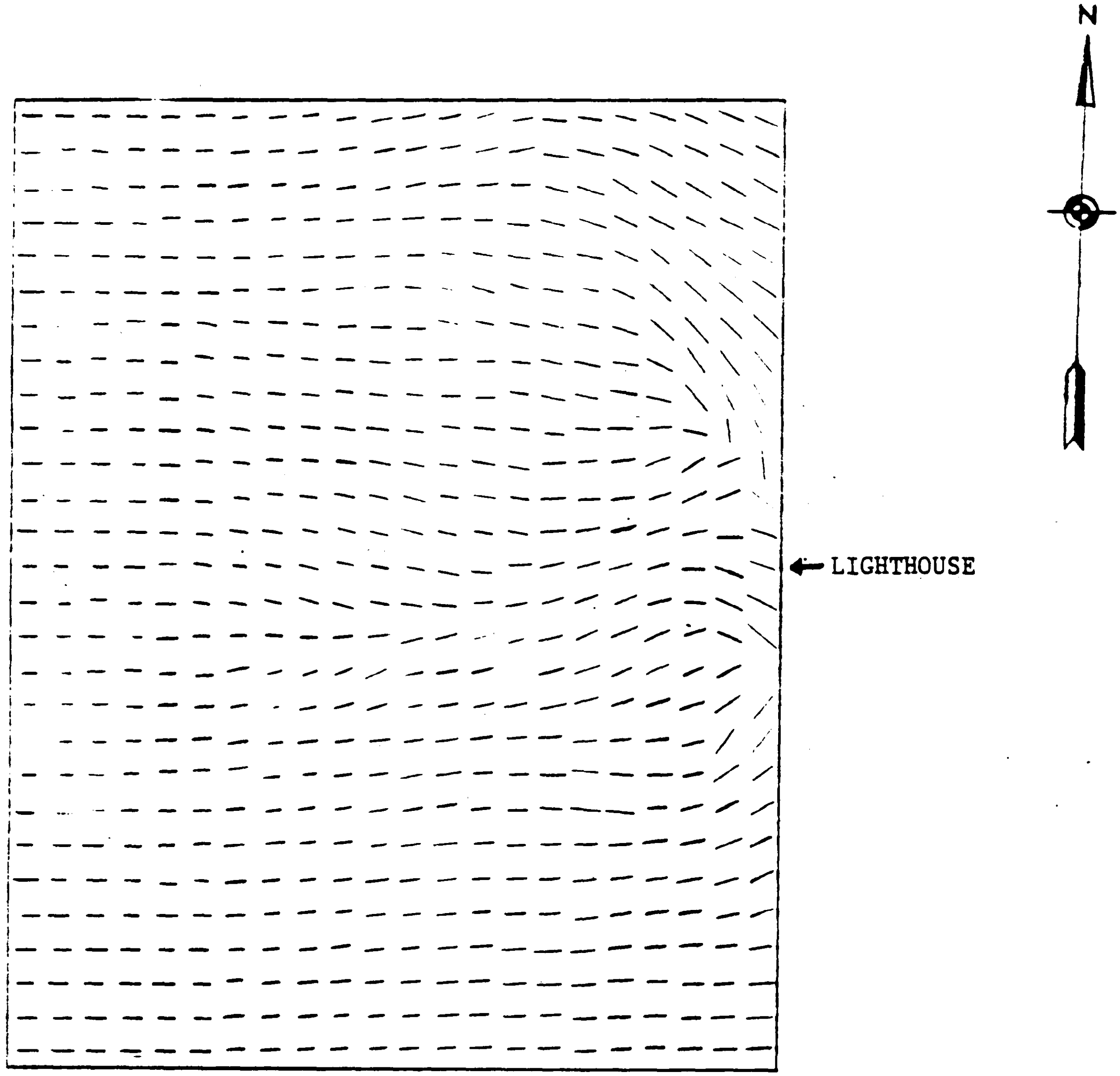

FIGURE 7

RCPWAVE WAVE ANGLES FROM SOUTHWEST

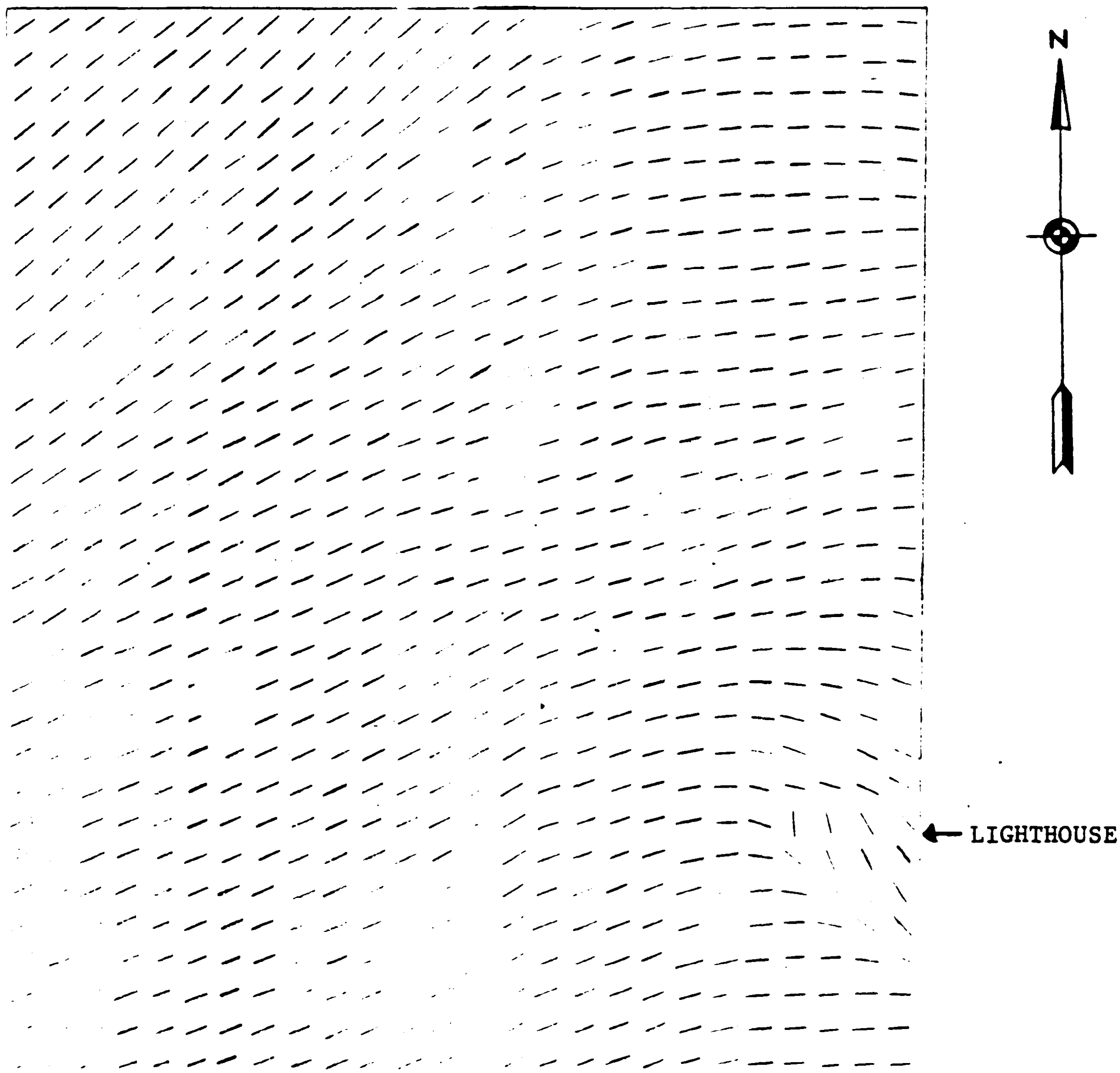

PHOTO 2
LONGSHORE TRANSPORT INDICATED BY 'RED WATER'

EROSION PROCESSES AND CRITICAL AREAS

INTRODUCTION

A study by consultants to the Corps of Engineers, (Woodward - Moorhouse and Associates, Inc., 1970) concluded that cliff recession at Gay Head is primarily the result of two broad processes.

i. Downslope movement of material by several different methods of erosion;

ii. The development of landslides

Down slope movement of material results in unconsolidated sediment, termed coluvium, at the base of the cliff. When this coluvium is removed, due to the action of waves, tides and longshore transport, new surfaces are exposed and the cliff face retreats.

These processes have caused the cliffs in the vicinity of the lighthouse to retreat at an average rate of 1 to 3 feet per year. As will be explained in more detail below, while the <u>average</u> rate of cliff recession is 1 to 3 feet per year, the rates along local portions of the cliff are commonly quite variable. A certain segment may remain stable for some years and then undergo several feet of retreat in a short period of time.

EROSION PROCESSES

Downslope movement of material from the cliffs and its subsequent removal from the area by waves and currents is the reason for the retreat of cliff faces in the area. What follows is a summary of the most effective processes of cliff erosion contributing to downslope movement at Gay Head.

A. Rain erosion. Most effective on lower flatter slopes where rain aids in removal of loose material from the slopes and creates gullies in sand and silt.

B. Storm erosion. Very effective on all slopes. The force of wind driven rain both removes material from the slopes and also imbeds moisture deeper into the cliff face where it can be effective at depth. Storm waves will remove material moved downslope quickly from beach face.

C. Frost Action. Effective on fine sands and silts saturated with water and clays that exhibit shrinkage cracks. Following a period of freezing and thawing, normally firm soils are plastic in texture and on steep slopes may become mudflows.

D. Swelling and shrinking of clays. Effective in exposing more surface area of clay and thus more vulnerable to weathering. Cracks will serve as conduits for water to enter to depths as much as 18 inches. Wetted surfaces are much more liable to failure than dry ones. Cracks also permit more frost action to occur. Clays rendered softer by water absorption through cracks are more easily eroded and removed from the slopes and beach faces.

E. Mudflows. Saturated silts and clays will loose strength and flow downslope. Commonly these flows will mix with coarser sediments and the entire mass will move downward. (See Photo 3.) Mudflows are a significant factor contributing to cliff erosion at Gay Head.

F. Groundwater seeps and springs. Surface mudflows, piping and collapse of large masses of sedimentary material are very common during and after periods of heavy rainfall. The role of groundwater at these times is very significant.

G. Landslides. Landslides at Gay Head take the form of very infrequent, but very effective, massive landslides or frequent slides of much lower magnitude. There are scars today of five major landslides in area. (See Photo 4.) A report written in 1786 (Baylies) describes "..four or five .." slides. Thus, at most, only one large slide has occurred since that report. Smaller slides are much more frequent and are a major factor in cliff retreat especially near the rims of the older larger slides.

The interrelation of so many erosional factors and the very complex nature of the geology at Gay Head prohibits any realistic hope of stopping the erosion and cliff retreat. The area will continue to be in a very dynamic state of flux and future planning for the area will have to take this factor into consideration.

As the material eroded from the cliff face falls to the base of the cliff (this material is termed coluvium in the Woodward - Moorhouse report previously cited), it is removed by wave and current action and the cliffs continue to recede. (See Photo 5.) If the coluvium were to accumulate, cliff recession at the lower slopes would cease and the cliff slope would be reduced as the erosion on the upper reaches continues. Eventually the cliffs would tend to become more stable as the slope lessens and a vegetative cover becomes established. It must be emphasized however, that the cliffs, subjected to rising sea level and the eroding effects of storms, will never be considered as totally stabilized. Further, even if some means were found to efficiently contain the coluvium at the base of the cliff, retreat of the upper part of the cliff would continue for some significant amount prior to relative stabilization of the entire cliff.

LANDSLIDES

Woodward-Moorhouse, on Figures 3 and 4 of their report, map five major landslides in the immediate vicinity of Gay Head Lighthouse. Plate 2 in this report, showing slides I-IV, is based on their figures. This plate is also based on photogrammetric mapping by the Corps of Engineers in 1967, aerial photography performed in 1969 and field observations made in 1970. Analysis of average inclination and degree of vegetation on the rear scarps of these landslides yields gross estimates of the relative ages of these slides. Slides IV is very old; slide III is of moderate age; and slides II and I are relatively recent occurrences with steep and unvegetated rear scarps. The major landslides in the study area are separated by relatively steep bluffs of fairly stable material.

PHOTO 3
MUDFLOWS CONTRIBUTE TO GAY HEAD EROSION

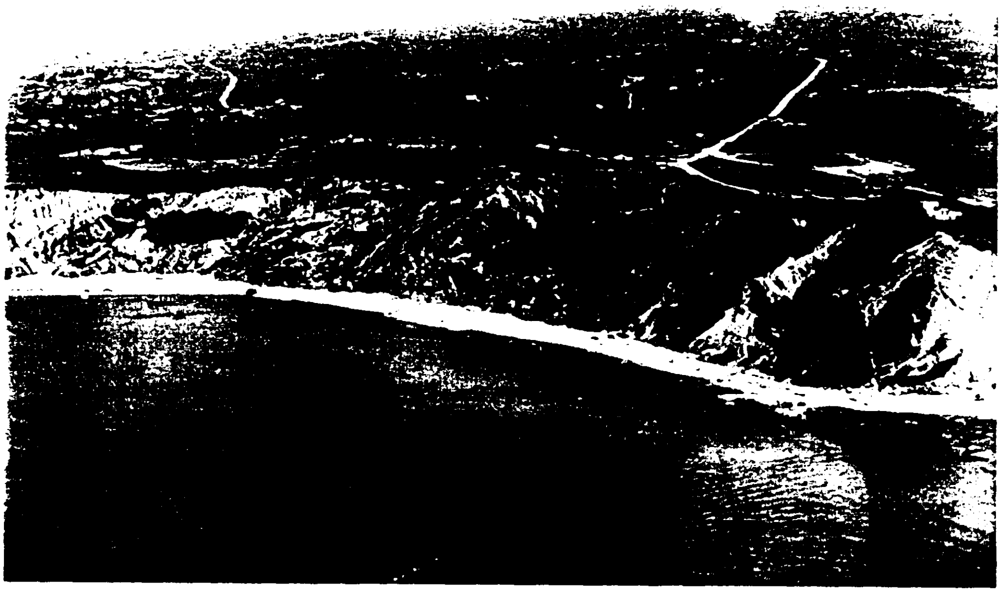

PHOTO 4
SCARS OF MAJOR LANDSLIDES AT GAY HEAD

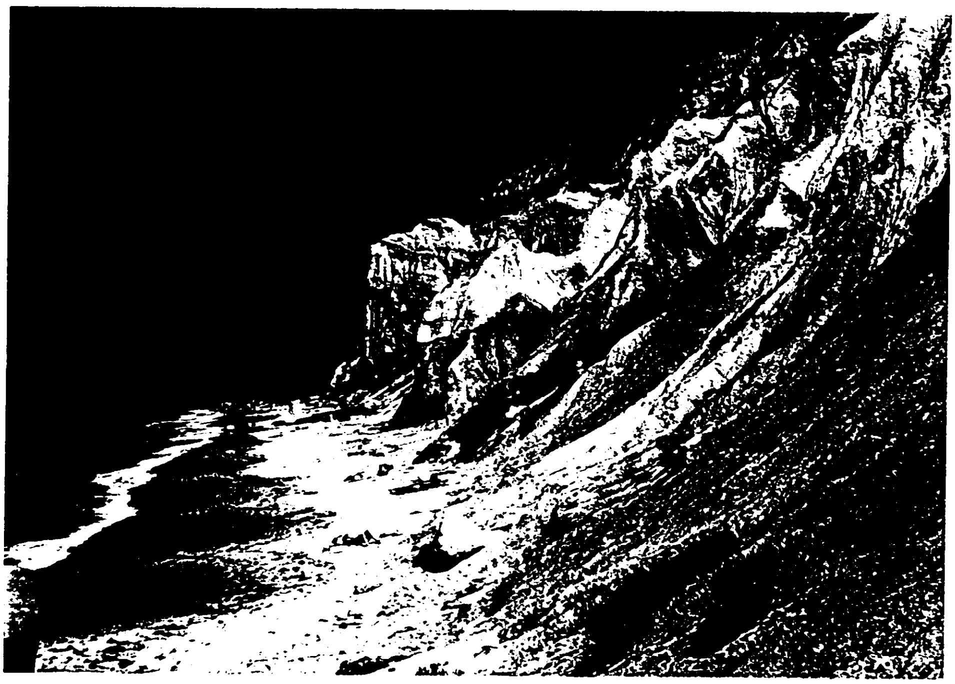

PHOTO 5
MATERIAL AT BOTTOM OF CLIFFS IS REMOVED BY WAVE ACTION

The 1973 Corps of Engineers report cited previously suggests that the major landslides were formed by either of two different processes. They all began as massive landslides and then continued cliff recession proceeded with a succession of smaller landslides which are confined to the upper slopes above the debris terraces. Subsurface drainage and seepage most probably are major contributing factors to the upper slope landslides. Other landslides develop as the bottom of the cliffs are undermined by wave erosion or piping by water seepage or by mudflows.

In addition to the major slides there are many smaller ones. Site visits by geologists and engineers, as described in the Woodward-Moorhouse report, showed 'erosion ... proceeding incessantly' especially during and immediately after periods of rain and snow melt. Saturated clay and clayey soil turned into mud and flowed downward 'forming a growing mud river as it comes down'. In the same report Barbara Chamberlin, a geologist with local expertise, reports a 'steady rain of pebbles and rocks ...' from undermined glacial sediments.

CLIFF RETREAT

Previous observations of rates of cliff recession have produced a wide variety of estimates ranging from 1 foot per year to 16 to 20 feet per year. Almost certainly the latter rate is excessive and probably concerns some localized accelerated rates due to landslides. The Woodward - Moorhouse report describes claims by residents that in 1930 the Coast Guard Station (Gay Head location) was 225 to 300 feet from the cliff edge. In 1970 the light was approximately 55 feet from the edge of the cliff. Assuming the validity of the estimates, an erosion rate of 4 to 6 feet per year could be postulated. The authors of the report are quick to point out that a local rate of recession should not be confused with the average rate of retreat exhibited by the cliffs as a whole in the entire study area.

Of special interest is the fact that recent (1988) measurements show the lighthouse to be 55 feet in from the cliff edge, the same as measured in 1970. Even allowing for a certain error in measurement, the closeness of these two estimates suggest that in the period 1970-1988, little cliff recession occurred. The wide disparity of historical estimates of cliff recession at Gay Head Light, the apparent 'hold' on erosion of the cliffs in the immediate vicinity of the lighthouse, and the erosion pattern of cliffs with a similar geologic composition and history (e.g. the area near Highland Light in North Truro on Cape Cod) all strongly suggest that at least sections of the cliff near Gay Head Light retreat in a step like blocky fashion. Under this scenario, certain portions of the cliff may remain stationary with little or no retreat observed for several years and then may undergo sudden and rapid erosion with substantial cliff recession occurring in a very short period of time.

CRITICAL AREAS

Clearly the most critical area in terms of imminent potential danger to the Gay Head Light is the cliff edge to the west of the lighthouse formed by the rear scarp of Landslide IV (see map, Plate 2). The light at that point is approximately 55 feet from the cliff edge. (See Photo 6.) At that distance, assuming an average rate of erosion of 1 to 3 feet per year, (see section on cliff recession for derivation of this rate) the lighthouse will

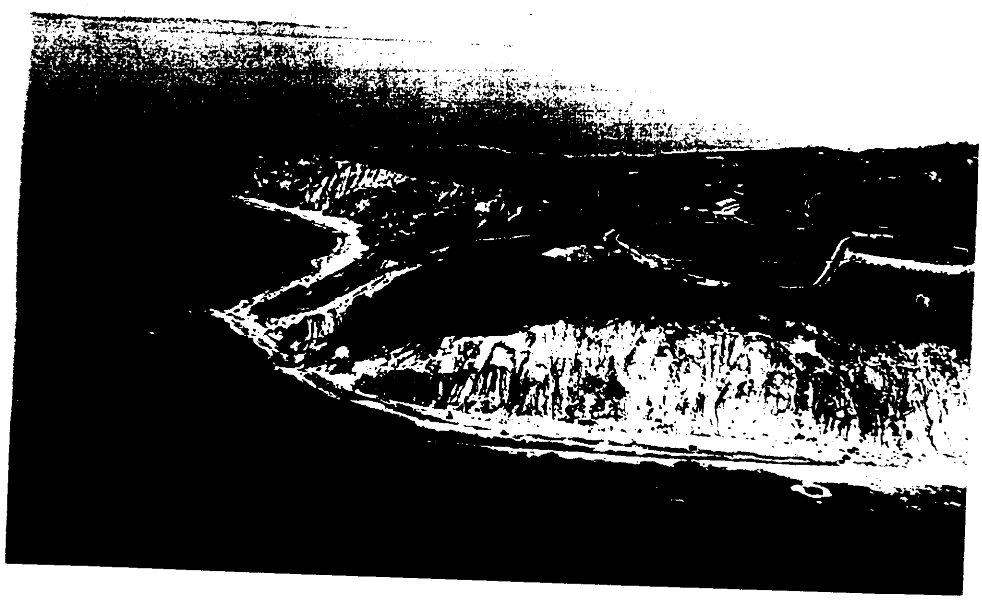

PHOTO 6
LIGHT STRUCTURE APPROXIMATELY 55 FEET FROM CLIFF EDGE

be lost to erosion in 25 to 50 years. The magnitude of the risk increases substantially when taking into account the probability of a catastrophic erosional event during which many feet of cliff might suddenly fall.

The cliff edges to the north and northwest of the light are 150 to 200 feet from the light and thus may not present as critical an erosion threat as the area discussed above. However, given the history of slope failure in the region, it is entirely possible that erosion which may substantially impact the stability of the light may occur also at those slopes further removed from the light.

SUMMARY

In summary it can be said that cliffs in the Gay Head area retreat on the order of 1 to 3 feet per year due to a combination of small landslides and other forms of mass wasting. Very infrequent catastrophic landslides result in large segments of sudden cliff retreat. Due to the very complex geology of the area, the local rates of erosion are extremely variable with some areas remaining dormant for several years and then becoming active and producing substantial cliff retreat in a short period of time. The effects of surface water infiltration and subsurface seepage, especially in the area of clay layers, are pronounced and contribute significantly to cliff erosion.

So complex is the erosion problem at Gay Head Light, that Barbara Chamberlin states in the Woodward - Moorhouse report "The problem of stopping the erosion seems, to me, unsolvable, and even significant control seems difficult." In short, there appears to be no practicable means by which cliff erosion in the area can be stopped. Attention will have to be focused on other means of protecting structures on top of and near to the eroding cliff edges at Gay Head Light.

PREDICTING FUTURE CONDITIONS

Bank erosion is the result of many factors. Theoretical methods have not developed to the point where they can accurately predict either rates or specific amounts of erosion at any given location. Although storm intensities can be predicted, the amount of erosion caused by a storm cannot be accurately predicted. The erosion rate depends upon the number and severity of storms, how much erosion these storms cause, and the geotechnical properties of the cliff face as it erodes. Forecasts of future bluff erosion conditions in this report will, therefore, be based on historical changes and/or certain assumptions.

The Gay Head Lighthouse is now 55 feet from the bluff at its closest point. Accepting that the average rate of erosion in the immediate vicinity of the lighthouse (location H on Plate 2) over the last 110 years has been 1.4 feet per year (see Table 3), one could say that the lighthouse will topple into the ocean in approximately 40 years. This is obviously an unrealistic prediction since the erosion rate at the cliff edge in this area has been demonstrated to be highly variable.

The analysis displayed in Table 4 reports an average recession rate at the lighthouse from 1951 - 1963 of 3.7 ft/yr. The data in table 2 shows that the bluff immediately to the north of the lighthouse lost 19 feet in one year. Allowing for these higher rates and assuming an average recession rate of 4 feet per year, all the land in front of the lighthouse would be gone in 14 years. It is extremely unlikely, however, that the bluff could support the large structure of the lighthouse on its extreme edge without failure. It is not possible, due to the variable and unstable nature of the cliffs, to predict specifically how much of a bluff safety zone apron would be needed to protect the cliffs from failure under the large mass of the lighthouse. Certain assumptions, therefor, must be made in order to arrive at reasonable estimates of when the critical erosion point will be reached.

If one assumes that the potential for immediate failure of bluff at the lighthouse becomes critical when only 20 feet of land separates the lighthouse from the cliff edge, (based on the 19 foot in one year failure referred to above), than the maximum and minimum life expectancy of the lighthouse at its present location ranges from 25 years at 1.4 feet per year to 9 years at 4 feet per year.

It must be emphasized that that these predictions are at best educated guesses based on analysis of past records. The extreme variability of the erosion and cliff recession rates do not allow for any precise forecasts of future events. What is very clear is that the potential for continued erosion and resulting loss of the lighthouse is very high and must be taken into consideration in any planning for the future, including the immediate future, of the structure.

The two scenarios predicted, 25 years and 9 years respectively to critical points, are indicators, and only indicators, of the potential for loss. The past history of the area strongly suggests, however, that this range is certainly possible, and offers a reasonable framework for planning purposes.

PLAN FORMULATION AND EVALUATION

The observations and analyses discussed and documented in this report clearly show the Gay Head Lighthouse to be in danger, very possibly imminent danger, of being lost due to slope failure. Several alternatives have been investigated in order to determine the best solution to the problem. The alternatives were analyzed based on cost estimates, ease of implementation, and environmental considerations. Cost estimates of the alternatives, as well as supporting documents, may be found in Appendix 2, Cost Estimates and Supplemental Information. Table 6, Comparison of Alternative Plans to Protect Gay Head Light, gives a summary and available costs of the alternatives investigated.

Preservation of the lighthouse can be accomplished by either stabilizing the cliff or moving the structure inland from the cliff edge. Cliff stabilization involves formulating alternatives to stop both erosion at the cliff base <u>AND</u> making the cliff face stable and not subject to the various forms of downslope movement including landslides now occurring there. Erosion at both the base and face of the cliff must be stopped in order to stabilize the cliff. To halt one without the other would either result in a stable cliff base and continued short to medium range recession of the top edge of the cliff, probably enough to seriously impact the lighthouse at its present location, or a temporarily stable cliff face which would shortly collapse as the base of the cliff became undercut. In either case the stability of the lighthouse would continue to deteriorate. Alternatives for

TABLE 6
COMPARISON OF ALTERNATIVE PLANS TO PROTECT GAY HEAD LIGHT

ALTERNATIVE		COSTS		
Number	Description	First Costs	Net Present Value of Costs over 50 Years at 10 Percent	COMMENTS
1	Sandfill - base of cliff	$ 9,000,000	$ 9,380,000	
2	Groins - base of cliff	$ 15,000,000	$ 16,175,000	Areas downdrift of groins may undergo accelerated erosion as result of groins.
3	Sandfill with groins	$ 24,000,000	$ 28,950,000	Areas downdrift of groins may undergo erosion.
4	Revetment - cliff base	$ 15,150,000	$ 18,556,000	Erosion of areas adjacent to revetment may cause revetment to unravel.
5	Offshore Breakwater	$ 15,000,000	$ 16,980,000	Requires considerable Coastal Engineering Design work. May not be environmently acceptable.
6	Artificial Seaweed	N/A	N/A	Plan not technically feasible.
7	Vegetation with Structural	N/A	N/A	Due to the historic nature of the cliffs at Gay Head, vegetation of the cliff face is not a feasible alternative.
8	Relocate Structure	$ 840,000	$ 920,000	Detailed design and cost estimates and analysis required to determine which of these two plans is more cost effective.
9	Construct New Structure	$1,920,000	$1,970,000	

the three situations described above (stabilization of cliff base; stabilization of cliff slope; and changing the location of the structure) are discussed immediately below.

STABILIZATION OF CLIFF BASE

Measures investigated to stop the erosion of the cliff base included placing sandfill along the beach area at the base of the cliff to stabilize the beach and the cliff area; constructing a series of groins at the base of the cliff to keep the beach from eroding and prevent the undermining of the cliff; using a combination of sandfill and groins; construction of a rock revetment in combination with upper bank stabilization; and construction of an offshore breakwater or use of artificial seaweed to reduce the wave climate in the area. Many of these methods were investigated in detail by the Corps of Engineers in their 1973 Beach Erosion Control Study for Gay Head Cliffs previously cited. Some of the data generated for that report are used for planning purposes in this document.

Alternative 1 - Sandfill

Sandfill is sand placed on the beach to form a wider berm so the storm waves break further offshore and do not impact the cliff base. Proposed fill dimensions are approximately 4,000 feet long by 150 feet wide with a berm elevation of 12 feet above mlw. Because wave action and longshore transport remove the sand and coluvium presently found at the cliff base, and certainly would erode any future sandfill placed there, a program of periodic nourishment would be required. Annual renourishment requirements in the range of 30,000 cubic yards have been estimated for the Gay Head Light area. It should be noted also that the present dry beach width at Gay Head Light is relatively narrow. Whether an artificially constructed 100 foot wide berm would be sufficiently stable in such an environment is problematical.

Alternative 2 - Groins

Groins are rock structures which protrude out into the ocean and trap the sand being transported in the longshore direction. A sand fillet will form on the updrift side of the groin. The downdrift side will be starved for sand and erosion in this area will accelerate. This may cause an indention in the cliff line which could flank the groin. In time, the erosion could go behind the groin and isolate an island of rock which would become ineffective and could form a hazard to navigation. Additionally, the groin would result in a negative visual impact on the rugged character of the beach in an area where there are currently no man-made structures.

However, a properly placed groin or series of groins, might reduce cliff undercutting by trapping sediment which otherwise would be removed from the area. Previously cited studies have proposed a series of 27 groins spaced at 200 foot intervals. The structures would be 400 feet long, 10 feet high and 8 feet in top width.

Alternative 3 - Sandfill with groins

Groins can also be used to stabilize placed fill. This alternative would help to partially solve the periodic nourishment problem associated with the sandfill option mentioned earlier. However, nourishment requirements would still be high since groins are often estimated to only reduce nourishment requirements by about one half. Furthermore, the erosion downdrift of the groins problem would still exist.

Alternative 4 - Revetment

Rock placed in a manner to armor the cliff base is called revetment. The revetment would most likely have to be constructed in combination with some form of bank stabilization at the top of the cliff. It would be impractical to revet the entire cliff face; the construction costs would be high. The bank stabilization at the top of the cliff could include vegetation along with drainage plans to keep the runoff away from the cliff's edge. Revetment will stop the erosion of the cliff behind it. However, erosion will likely continue at the structure's toe and eventually the revetment will be undermined and fail. The comparison of alternative plans to protect Gay Head Light presented in Table 6 indicates that even if the 4,000 foot long revetment were to have an economic life of 50 years, which is unlikely in the high energy environment found at Gay Head, it is not the most economically feasible alternative considered. Further, only a limited distance of cliff can be protected, causing the area adjacent to the revetment to erode and the revetment itself to unravel.

A detailed plan of a revetment suitable for the protection of Gay Head Light is beyond the scope of this report. For illustrative purposes, however, a typical cross section of a revetment is seen in Figure 8. An analysis of the situation, suitable for general planning purposes only, supplies the following design data.

a) deep water wave height (from SEAS data) of 20 feet

b) estimated vertical run-up on rough quarry stone of 16 feet

c) revetment slope of 1.0 V on 1.5 H

d) armor layer thickness of 15 feet
underlayer thickness of 2 feet
bedding layer thickness of 1 foot

e) cross section of structure is 850 square feet

f) linear dimension of 4,000 feet (length of Coast Guard property)

g) volume of revetment using above dimensions is 3.4 million cubic feet. Assuming 25% voids and a rock density of 165 lbs/cu ft results in a weight of 210,000 tons

Gabions have been used in the coastal environment as a form of low cost shore protection. Gabions are rectangular steel wire baskets that are filled with stones. They have a variety of applications such as retaining walls and revetments. Gabions could be used with filter fabric and stone toe protection in an attempt to armor a cliff such as Gay Head Light. However, CERC does not recommend their use in high energy environments, such as found near Gay Head Light, because of the flexing and wire fatigue and failure that commonly occurs. Additionally, gabions are not recommended in active surf zones where sand and debris provide an abrasive environment which can cause wear and eventual failure of the PVC coating of the wire baskets.

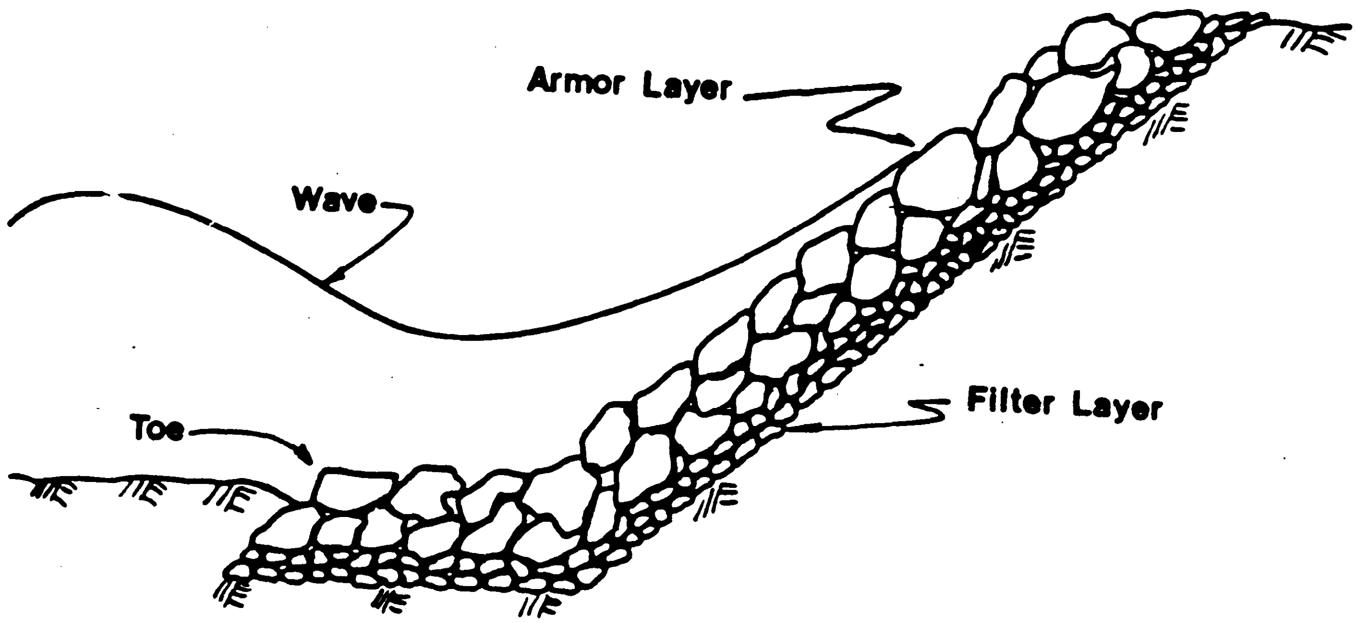

FIGURE 8 - TYPICAL REVETMENT SECTION

Alternative 5 - Offshore Breakwater

Breakwaters, as the name implies, are rock structures built offshore to break the waves. They would reduce the size of the waves impacting the cliff base by causing them to break offshore. In addition, like groins, they interrupt longshore transport. Longshore transport is caused by the energy of waves which strike the shore obliquely. If the waves are interrupted over a section of beach, the lack of wave energy will cause the sand normally transported past the section of beach to be deposited. If the breakwater is too close to the shore, a tombolo will form connecting the breakwater to the shore. This will react the same as a groin and cut off longshore transport and cause downdrift erosion. The breakwater must be constructed far enough offshore to allow waves to diffract around it, thereby allowing enough sand to pass between the breakwater and the beach preventing downdrift starvation. Two negative arguments may forcibly be made against this alternative. The first is cost. Breakwaters are large structures which require careful construction under difficult conditions. Construction of a breakwater of sufficient size and effectiveness at Gay Head Light could cost in the neighborhood of 4 million dollars. The second is the fact that breakwaters are viewed by some as hazards to navigation and/or as visually unacceptable at an historic landmark such as Gay Head Cliffs.

Alternative 6 - Artificial Seaweed

Artificial seaweed refers to strips of cloth-type material suspended offshore which act to reduce wave energy approaching the beach. In this manner they tend to exert the same effect as a breakwater although on a smaller scale. CERC does not recommend artificial seaweed in high energy areas for the prevention or attenuation of wave erosion.

SLOPE FACE STABILIZATION

Slope stabilization measures allow the cliff to maintain a steeper angle. However "as the bottom of the cliffs are eroded away by storm and wave action" (Woodward - Moorhouse & Assoc. page 17) slope failure will proceed and the cliffs will eventually recede further. Slope stabilization measures investigated include vegetation and dewatering.

Alternative 7 - Vegetation with structural slope stabilization

Vegetation of the cliff area should make the bank more stable and slow the erosion process. Extensive horticultural, soil, slope analyses and hydrologic studies would be needed to determine the vegetation procedures required to properly address the problem or to determine whether this type of solution were even feasible. Vegetation, if it could be maintained, would help to stabilize the bank area, but it will not completely stop the erosion.

Other areas of the country have been stabilized using a combination of structural and vegetative slope protection. These structural measures include terracing the slope, reveting the base and stabilizing the bank enough to allow the vegetation to root so that its chances of survival would be greatly increased.

In the case of Gay Head, the historic significance associated with the colors of the cliff face, make it infeasible to use vegetation as a form of slope stabilization in this area.

In areas with clay strata, ground water is often a cause of erosion. Water seeps into the ground until it hits an impermeable layer of clay and then flows generally horizontally over the surface of that impermeable layer. As it moves through the soil, the water increases pore pressure and tends to swell and move apart the layers of rock material making up the cliffs. By flowing between the soil layers it also lubricates the interface between layers. This allows one layer to slide over another, when pushed by gravity, and eventually fall. When the water flowing between the layers reaches the cliff face, it flows down the face, carrying clay along with it. There is ample evidence as described in the section of this report on Erosion Processes and Critical Areas to support the conclusion that groundwater and seepage contribute significantly to cliff erosion at Gay Head.

There are various ways to dewater the soil. One is to drill wells along the top of the cliff and pump the water out. Another is to drill down through the impermeable layers allowing water to flow down through the drilled holes instead of flowing sideways and down the cliff. A third method of dewatering is to drill a pipe into the side of the cliff and allow the water to flow out through pipes instead of out through the layers. All methods would temporarily reduce the failure of the cliff and keep large blocks of material from falling over the edge.

Engineering methods are available to monitor rates of slippage incurred during slope failure. These rates are measured with the use of a borehole extensometer. Displacements of 1/1000 of an inch can be determined. In that the Gay Head Light is so close to the cliff edge and that some significant time may be needed to calibrate the instrument and gather sufficient measurements for valid comparisons, it is doubtful that the use of such an instrument would be beneficial or warranted at Gay Head Light.

CHANGE OF LIGHTHOUSE LOCATION

Alternative 8 - Relocate Structure

Changing the location of the lighthouse so that it is situated further from the cliff edge can be accomplished by moving the existing structure or building a new one far enough in from the cliff.

Moving the lighthouse may at first appear to be an unlikely solution. It is estimated to weigh several hundred tons. However, there are a number of contractors who do such work. The Move the Lighthouse Committee in North Carolina has investigated the possibilities of moving Cape Hatteras Light. Cape Hatteras Light is 208 feet tall and weighs approximately 2,600 tons. This is approximately 4 times the height of Gay Head Light. Appendix 2 carries a letter from the International Association of Structural Movers stating that there are several contractors in the country capable of moving Cape Hatteras Light.

After the structural integrity of the lighthouse is investigated and any repairs made, the moving process could begin. Holes would be drilled in the base of the lighthouse and beams placed through them. The beams ride on wheels which ride on tracks similar to railroad tracks. The largest part of the job is building the tracks. Movement consists of rolling the lighthouse along the tracks.

Alternative 9 - Construct new structure

The last alternative is to abandon the lighthouse and build a new one. It would be best to dismantle the old lighthouse otherwise it could create potentially dangerous rubble at the bottom of the cliff when it falls over. It would also mean losing a structure which has served its purpose well since 1856. The new lighthouse could be identical in structure, possibly using the same material as the old structure, or it could be more modern.

CONCLUSIONS

Gay Head Lighthouse is an important navigational structure and a well recognized historical monument. It is located on top of high cliffs at the western end of Martha's Vineyard Island. The structure is presently very near the cliff edge, see map on Plate 2, and erosion of these cliffs has prompted well deserved concern about the future stability of the lighthouse.

A very significant reason for concern is the unconsolidated nature of the material composing the cliffs. The sediments of the Gay Head Light area have been described as Cretaceous and Tertiary materials displaced by glacial action and overlain by more recent glacial deposits. The sediments consist predominantly of sands, gravels and clays all of which are unconsolidated and thus subject to rapid erosion. The geological history of the area has resulted in a very complex structure of sedimentary materials. Iron staining of sediments and small springs along the cliff faces are commonly observed, both strong indicators of abundant groundwater seepage. The combination of clay layers, unconsolidated sediments and abundant groundwater is a condition very conducive to erosion.

The cliffs are receding due to several natural erosion processes including wave undercutting, groundwater seeps and springs, and infrequent catastrophic landslides. Data from several sources was used to compile information on rates of cliff retreat. Recession rates have been estimated as ranging from 1 foot per year to between 16 and 20 feet per year. Almost certainly the latter rate is excessive and probably concerns some localized accelerated rates due to landslides.

In conclusion, it can be said that cliffs in the Gay Head Light area retreat on the order of 1 to 3 feet per year due to a combination of small landslides and other forms of mass wasting. Very infrequent catastrophic landslides result in large segments of sudden cliff retreat. Due to the very complex geology of the area, the local rates of erosion are extremely variable with some areas remaining dormant for several years and then becoming active and producing substantial cliff retreat in a short period of time.

Bank erosion is based on many factors. Theoretical methods have not developed to the point where they can accurately predict erosion. Therefore, forecasts of future conditions in this report will be based on historical changes and reasonable assumptions. It is estimated for planning purposes that between 9 and 25 years remain until the lighthouse can be considered to be in immediate danger of collapse. This estimate is based on an average cliff recession rate directly adjacent to the light structure, which ranges from a minimum of 1.4 feet per year to a maximum of 3.7 feet per year. The estimated safe life of the structure is also based on assuming a critical buffer zone of 20 feet of land separating the lighthouse from the cliff edge. The two scenarios predicted, 25 years and 9 years respectively to critical points, are indicators, and only indicators, of the potential for loss. The past history of the area strongly suggests, however, that this range is certainly possible, and offers a reasonable framework for planning purposes.

In the general case lighthouses and other structures which are in danger of being lost to cliff erosion can be preserved for some period of time by either stabilizing the cliff or moving the structure inland. Several alternative plans to accomplish these ends are proposed in the report and summarized on Table 6.

RECOMMENDATIONS

Investigations performed during this study, as well as conclusions reached in prior studies, clearly indicate that unless some preventative measures are taken, Gay Head Lighthouse will fall into the sea due to erosion of the bluff upon which it sits. Given the proximity of the structure to the cliff edge, measured as 55 feet in August, 1988, it is reasonable to expect that the probability of loss of the lighthouse to erosion will become critically high within the next very few decades. It is the recommendation of this report, therefore, that some remedial action be taken immediately.

The specific alternative chosen to preserve the lighthouse will depend on evaluation of further engineering, social and economic analyses not provided for in the scope of this report. Final consideration of alternatives should include the following factors:

A. The area has been declared a Registered National Monument.

B. The attractive colors of the cliff, long a strong international tourist attraction, owe their freshness and intensity to the continual and steady erosion of the cliff faces. Any plans considered which would halt or significantly reduce the rate of cliff erosion may very well result in a marked loss of color exhibition.

C. The relatively narrow beach fronting the cliffs under the lighthouse is a popular spot for swimmers and sunbathers in season. Some of the alternatives discussed in this report would significantly decrease the dry beach width of the area and/or render the beach much less aesthetically pleasing than it is now.

Finally, it is recommended that a monitoring survey program, similar to that performed by Coast Guard personnel at Highland Light in North Truro, Massachusetts and described in Appendix 1 of this report, be immediately implemented at Gay Head Light. Such a program would furnish a data base of survey information upon which more precise estimates of future conditions may be prepared. Such a program would also insure periodic inspection of the cliff edges and may lead to early warning of impending landslide or other large scale slope failure.

APPENDIX 1

MONITORING SURVEY PROGRAM

APPENDIX 1
MONITORING SURVEY PROGRAM

The Coast Guard has maintained some kind of ongoing erosion survey program at many of their lighthouse locations. The data so obtained are useful in monitoring the rates of cliff recession as they affect the safety and siting of the light structures. Most notable of these is the very complete monitoring program conducted at Highland Light.

The Coast Guard has maintained an erosion record at Highland Light Station for a number of years. About a dozen stakes were placed at approximately 50 foot setbacks from the bluff and the distances from the stakes to the bluff was measured every month.

The recommendation for Gay Head Light would be to initiate a program similar to the at Highland Light Station and to tie the entire survey program in to the property bounds at the back of the Coast Guard property. A baseline should be set up using the property bounds, and then the erosion survey stakes should be tied into this baseline. If any of these stakes are lost or moved, the new stakes would be able to be replaced and there would be no need for a gap in the historical information for that area.

Historical evidence of cliff erosion at Gay Head, gained from past surveys and discussed previously in this report, demonstrates quite clearly the high risk of bluff failure and structure loss present at Gay Head unless corrective action is taken. The purpose of a monitoring survey program at this site would be to provide a sort of early warning system at Gay Head. With relatively little expenditure of either funds or manpower, a once a month short to mid range program could be initiated.

A series of stakes at 25-50 foot intervals could be installed along a 400 foot front parallel to the edge of the bluff. The distance from the stakes to the edge of the cliff would be measured at monthly intervals for as long as the program was active. It is recommended that the survey points would be set up as a series of lines radiating from the light structure. Two stakes would be set along each ray. One stake about 25 feet in from the edge and the second one 25 feet further in along the ray. The ray configuration would serve as a tie in for each of the survey points to a recognizable landmark. The requirement of having two stakes would allow a more accurate line of sight when measuring the distance from the cliff edge to the near stake. The presence of a second stake would also insure that a 'back up' stake remains in case of marked cliff failure where many feet of cliff might erode suddenly. If this program is to be initiated, it is strongly recommended that it be started immediately.

APPENDIX 2

COST ESTIMATES AND SUPPLEMENTAL INFORMATION

APPENDIX 2
COST ESTIMATES AND SUPPLEMENTAL INFORMATION

TABLE OF CONTENTS

COST ESTIMATES

Cost estimates have been put in the net present value format and discounted at an interest rate of 10 percent over a 50 year period of analysis to permit a comparison of the costs of the alternatives in accordance with the Economic Analysis Handbook (July 1980)-NAVFAC, p. 442.

ALTERNATIVE 1 - MEASURING BANK SLIPPAGE FOR EARLY WARNING

No formal cost estimate was prepared for this alternative since it would only give early warning of the failure of the bank, and there are many different ways of measuring the slippage. There is however, a letter pertaining to this alternative included in this appendix.

ALTERNATIVE 2 - VEGETATION ON CLIFF WITH STRUCTURAL SLOPE STABILIZATION

No formal cost estimate was prepared for this alternative since there are so many choices as to the materials to use for the structures and the vegetation.

ALTERNATIVE 3 - SANDFILL

FIRST COST

Sandfill	400,000 cy @ $15/cy	$6,000,000
Contingencies		$1,500,000
Subtotal		$7,500,000
Engineering and Design		600,000
Subtotal		$8,100,000
Supervision and Administration		900,000
TOTAL FIRST COST		$9,000,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$9,000,000
Periodic Nourishment*	380,000
NET PRESENT VALUE	$9,380,000

* Note - Nourishment is estimated at 5% of original amount of fill per year.

ALTERNATIVE 4 - GROINS

FIRST COST

Rock	250,000 tons @ $40/ton	$10,000,000
Contingencies		$ 2,500,000
Subtotal		$12,500,000
Engineering and Design		1,000,000
Subtotal		$13,500,000
Supervision and Administration		1,500,000
TOTAL FIRST COST		$15,000,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$15,000,000
Annual Maintenance	
$119,000/yr x (9.9)	$ 1,175,000
NET PRESENT VALUE	$16,175,000

ALTERNATIVE 5 - SANDFILL WITH GROINS

FIRST COST

Sandfill	400,000 cy @ $15/cy	$ 6,000,000
Rock	250,000 tons @ $40/ton	10,000,000
Subtotal		$16,000,000
Contingencies		4,000,000
Subtotal		$20,000,000
Engineering and Design		1,600,000
Subtotal		$21,600,000
Supervision and Administration		2,400,000
TOTAL FIRST COST		$24,000,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$24,000,000
Annual Nourishment and maintenance	
$500,000/yr x (9.9)	$ 4,950,000
NET PRESENT VALUE	$28,950,000

ALTERNATIVE 6 - REVETMENT

FIRST COST

Rock	225,000 tons @ $45/ton	$10,125,000
Contingencies		2,500,000
Subtotal		$12,625,000
Engineering and Design		1,010,000
Subtotal		$13,635,000
Supervision and Administration		1,515,000
TOTAL FIRST COST		$15,150,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$15,150,000
Annual Maintenance	
$344,000/yr x (9.9)	$ 3,406,000
NET PRESENT VALUE	$18,556,000

ALTERNATIVE 7 - BREAKWATER

FIRST COST

Rock	250,000 tons @ $40/ton	$10,000,000
Contingencies		2,500,000
Subtotal		$12,500,000
Engineering and Design		1,000,000
Subtotal		$13,500,000
Supervision and Administration		1,500,000
TOTAL FIRST COST		$15,000,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$15,000,000
Annual Maintenance	
$200,000/yr x (9.9)	$ 1,980,000
NET PRESENT VALUE	$16,980,000

ALTERNATIVE 8 - ARTIFICIAL SEAWEED

No formal cost estimate was prepared for this alternative since it would not be effective in this area.

ALTERNATIVE 9 - MOVING THE EXISTING STRUCTURE

Preliminary inquires indicate that the cost of relocating a structure the size of Gay Head lighthouse could be about $500,000. See the letter from LaPlante - Adair Co., Contractors and Moving Engineers in this appendix. A cost of $600,000 has been used in this study to allow for structural modifications.

FIRST COST

Relocation	$ 600,000
Contingencies	100,000
Subtotal	$ 700,000
Engineering and Design	56,000
Subtotal	$ 756,000
Supervision and Administration	84,000
TOTAL FIRST COST	$ 840,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$ 840,000
Annual Maintenance	
$8,000/yr x (9.9)	$ 80,000
NET PRESENT VALUE	$ 920,000

ALTERNATIVE 10 - CONSTRUCTING A NEW LIGHTHOUSE

According to the U.S. Coast Guard, the construction of the new Great Point Lighthouse, Nantucket, Massachusetts was completed in late 1985 at a cost of approximately $1,000,000. This study estimates the cost of construction of a new lighthouse at Gay Head to be in the range of $1,100,000 to $1,500,000. A figure of $1,300,000 is used for cost estimates.

FIRST COST

Constructing new lighthouse	$1,300,000
Contingencies	300,000
Subtotal	$1,600,000
Engineering and Design	128,000
Subtotal	$1,728,000
Supervision and Administration	192,000
TOTAL FIRST COST	$1,920,000

NET PRESENT VALUE (NPV) YEAR ZERO

Total First Cost	$1,920,000
Annual Maintenance	
$5,000/yr x (9.9)	$ 50,000
NET PRESENT VALUE	$1,970,000

ALTERNATIVE 1 - MEASURING BANK SLIPPAGE FOR EARLY WARNING

Howard B. Dutro

P.O. Box 191
Delmont, S.D. 57330

Phone
Office: 605-779-3201
Home: 605-779-3191

January 18, 1988

Mr. Tom Chisholm
Dept. of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02254-9149

Dear Mr. Chisholm:

Thank you for your letter of 11 January, describing slope failures adjacent to the lighthouses.

Probably most sea cliff failures are due to toppling induced by wave erosion at cliff bases. However, looking at the photos you enclosed, the slope angles look a little too flat for this to have been the primary mode. I wonder if some of the failures may be due to percolation of water downward to impermeable layers which dip toward the sea, with subsequent outward movement of the blocks along these layers?

If so, the initial and subsequent displacements of unstable blocks could be detected using Multiple Position Borehole Extensometers. The instruments could be installed in holes drilled either from the surface immediately behind the crest of the slope or from the slope face, depending on the attitude of the potential failure plane or planes. If, on the other hand, toppling were to be the principal mode of failure, tilt meters could be used to detect early rotation of failing blocks.

My own preference is for borehole extensometers because the can be arranged to test greater expanses of ground, and because they can detect displacements of extremely small magnitudes. This is important because, of course, the name of the game is to detect impending problems early enough to permit remedial action to be taken. If in fact some of the problems are due to water migration along impermeable beds, the most likely remedies would be dewatering of the overlying permeable beds and diversion of rainfall or snowmelt sources in the area behind the cliff.

If either your office or the Coast Guard can give me a more detailed description of the geology; i.e., the character, strike, dip, thickness, etc. of the beds, I will be happy to make a more detailed proposal. In the meantime, I would guess that a typical borehole extensometer equipped with eight mechanical transducer and dimensioned for installation in a 400 ft. 3 to 4 inch hole might cost about $3,000 (plus drilling and installation labor). The 400-ft length would place the point of the hole well inshore from the lighthouse, thus referring subsequent measurements to a point presumably stable and fixed in space. Sensitivity would be on the order of 0.001 inches or greater, with a useful range of several inches. Generally, the hole would be inclined with respect to the bedding, in order to intersect as many potential failure planes as possible at angles of perhaps 25 to 45 deg. Such an instrument would be read out using a depth micrometer or vernier caliper.

A similar instrument could be provided, but with remote electronic readout, at a cost of perhaps $6,000 - $7,500. I personally favor the simpler and less expensive mechanical variety, for several reasons. I would prefer to see the extra money put into additional instruments, rather than into possibly pointless refinements. I also think it is a good idea to have a living, breathing person at the site as frequently as possible not only to make regular engineering observations but also to inspect and maintain the instruments. Finally, I am opposed to the general idea which seems to be implicit in some forms of instrumentation which is to automate data acquisition and record data en masse. This seems to me to be relegating perhaps one of the most critical tasks in geotechnical engineering to people who understand the computer-based data acquisition apparatus, regardless of how well or how poorly they understand the fundamentals nature and risks of the problem.

At any rate, let me know what further information I can provide. I have added your name to Terrasciences' mailing list, and I am enclosing two copies of the "Field Notes" issue you have already seen.

I am sending a copy of this letter along to Gordon Patrick, so that he will know you and I are in contact. Gordon and I fought the good fight on a number of projects for the Corps of Engineers, notably slope instrumentation at Libby Dam (Montana) and instrumentation of a sensitive foundation at Green Peter Dam (Oregon). Among many other projects I have been involved in for the COE are Raystown Lock and Dam (Maryland), Hannibal Lock and Dam (Pennsylvania), Clarence Cannon Dam (Missouri), Carters Dam (Georgia), Bankhead Lock and Dam restoration (Alabama), Stockton Dam (Missouri), Chatfield Dam (Colorado), Snetisham Pumped Storage Project (Alaska), and on and on.

With thanks again for your interest in contacting me, I remain,

Yours very truly,

Howard Dutro

Howard B. Dutro

enc.

ALTERNATIVE 2 - VEGETATION ON CLIFF WITH STRUCTURAL SLOPE STABILIZATION

Woman 'holds up' Montauk Point bank

By PATTY KOLLER

Thick fog lent a desolate air to Montauk Point, N.Y., a surf-swept area on the eastern tip of Long Island. Through the mist one November afternoon, 77-year-old Giorgina Reid deftly stepped up a terraced 45-degree slope to meet a visitor.

"Count to 16 and hold your ears," warned Reid. A skull-splitting fog horn near the Montauk Lighthouse intermittently blasted only a few yards away, atop the steep bluffs that raise Montauk Point up some 85 feet above the ocean.

Over the course of 15 years, Reid has almost single-handedly transformed the once-eroding sand cliffs into beach grass-covered slopes.

Reid is well acquainted with the horn's characteristics and, for that matter, most all of the specifics of the 189-year-old lighthouse. Since 1970 the Queens, N.Y., resident has once or twice a week traveled by car the length of Long Island to get there.

Armed on these biweekly visits with rake, hoe, lumber, bags of reeds and Donald, her husband of 52 years, Reid has, in a somewhat simplistic explanation, graded the bluffs to an angle of 45 degrees or less, formed terraces by placing boards horizontally across the resulting slopes, filled the spaces behind the boards with reeds and sand, then waited as beach grass took hold.

"I was amazed to find that beach grass came up of its own accord once I stilled the sand," said Reid. "The (grasses) need peace and quiet — we all do to grow."

Reid's efforts at Montauk Point follow her own method of erosion control that she calls "Reed-Trench Terracing". It is all outlined in a book she wrote — "How to Hold Up A Bank" — and in Letters Patent 3,412,561, on file with the U.S. Patent Office since 1968.

In what amounts to a monumental change of course, the bank at Montauk Point upon which Reid has been toiling for so long is now "holding up beautifully," said Coast Guard Petty Officer W. Gene Hughes, who is keeper of the Montauk Lighthouse.

President George Washington commissioned the Montauk Lighthouse, one of the oldest in the nation, and when it was completed in 1797 its sturdy base rested 297 feet from the edge of the high bluff above the ocean. By the late 1960s only 60 feet of that land remained — the wind, rain and strong-of-heart climbers having made relatively quick work of eroding the rest.

In the late 1960s Reid learned of the situation from friends who fished at Montauk. "They said the lighthouse would fall into the sea by 1985," recalled Reid, a tiny woman who appears to be 20 years younger than her actual age. "I wanted to get my paws at it."

REEDS, according to Giorgina Reid, are the key to her erosion control method. Here she places them in terraces that will eventually grow beach grass and stabilize the bank below the Montauk (N.Y.) Lighthouse.

Reid's paws stopped the erosion in its tracks — today the edge of the cliff remains where it was when she started.

She originally developed her erosion control method in order to save her bluff-top summer home on Long Island's north shore after a 1962 storm devastated the cliff only 15 feet away. The storm littered the beach below with the reeds that became "the nucleus of my method," said Reid, her face windburned and her navy blue coat dusted with sand.

The reeds, she explained, serve as gaskets — they keep the sand from slipping out from under the boards that containing the terrace, and they send water up to grass roots through capillary action. After the grasses take hold, the boards can be removed and the bank will remain stable.

Reid said that taking out a patent on the method wasn't to make money but to ensure that if it's done wrong, she won't be blamed for it.

Contractors hired by the Coast Guard in 1971 to arrest the erosion at Montauk Point after Reid demonstrated how the technique worked, did it wrong, Reid said.

Nonetheless, the Coast Guard has been helpful to Reid's project, throughout the years contributing more than $150,000. Reid's husband figures, she said, that the couple has spent close to $40,000 of their own money on the Montauk project.

"Over the years it doesn't matter, it goes bit by bit," said Reid, who broke her ankle last spring while working on the bluffs.

By now Reid has completed most of the work the federally-owned banks of Montauk Point require. The rest is owned by the state, and Reid flatly said, "the state has no money." No money, that is, to spend on Reid's erosion control project.

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"Her work is not going to mean anything on the Coast Guard property unless the state does their part," said Hughes.

Reid has estimated that she needs $50,000 to complete her work — 300 linear feet of bluff on the state side — and fully protect the Montauk Lighthouse from crumbling with Montauk Point into the ocean.

But at this point, the money isn't likely to come from the state of New York.

"We don't have the money in the budget at the present time," said John Sheridan, general manager of the Long Island State Park Commission. Sheridan said he has heard nothing of late from either Reid or the federal government on the specifics of Reid's erosion project and has received no indication on how Reid plans to spend $50,000. There are 25 state parks in Nassau and Suffolk counties, he said, and "each of those has a Giorgina Reid-type project."

If the state were to deem it worthwhile to sink money into the project, Sheridan said, a contract process would follow. "Maybe what Mrs. Reid has in mind would cost $30,000 under public bid."

That's not likely to sit well with Reid, who has already demonstrated her preference for doing the work rather than watching someone else do it incorrectly.

"It's a long, painstaking process she goes through," said Hughes, who has watched her go through it for the two years he's been stationed at the Montauk Lighthouse. "It works well but it takes care — it's not the type of work you can contract out."

Reid said that she was doing the best she could on the state side with the limited resources at her disposal. She had also formed a non-profit organization — the Montauk Point Erosion Control Project, Box 995, Montauk, N.Y. 11954 — so she could collect donations to continue her work.

"The lighthouse is my only child," said Reid, wrapping up her theories about erosion control. "You've got to give or it will be taken from you."

2 of 2

ALTERNATIVE 9 - MOVING THE EXISTING STRUCTURE

LaPLANT-ADAIR CO. • *Contractors and Moving Engineers*

1200 WEST INDUSTRIAL AVENUE
BOYNTON BEACH, FLORIDA ~~33435~~ 33426
PHONE (305) 737-8188

February 10, 1988

Mr. Tom Chisholm, Engineer
CENEDPL-C
Corp. of Engineers
424 Trapelo Road
Waltham, Massachusetts 92254

Dear Mr. Chisholm:

We are enclosing a few reproductions of photographs showing four or five interesting jobs we have completed.

Not shown are the hundreds of buildings, several entire towns, several bridges, 30 to 35 additional elevated tanks, heavy machinery, chimneys, and other heavy and difficult moves.

Whenever you are ready to proceed with this work we will be glad to work with you. If you so desire, we can visit you and advise you as to the practical applications necessary to successfully complete the relocation of the lighthouses you wish to be moved. For this inspection service we charge $500.00 per day portal-to-portal, plus all travel expenses.

Please advise if we can be of service to you, and call us collect at Area Code 305, 737-8188. Effective April 16th, our new Area Code will be 407.

Respectfully submitted,

LaPLANT-ADAIR CO.

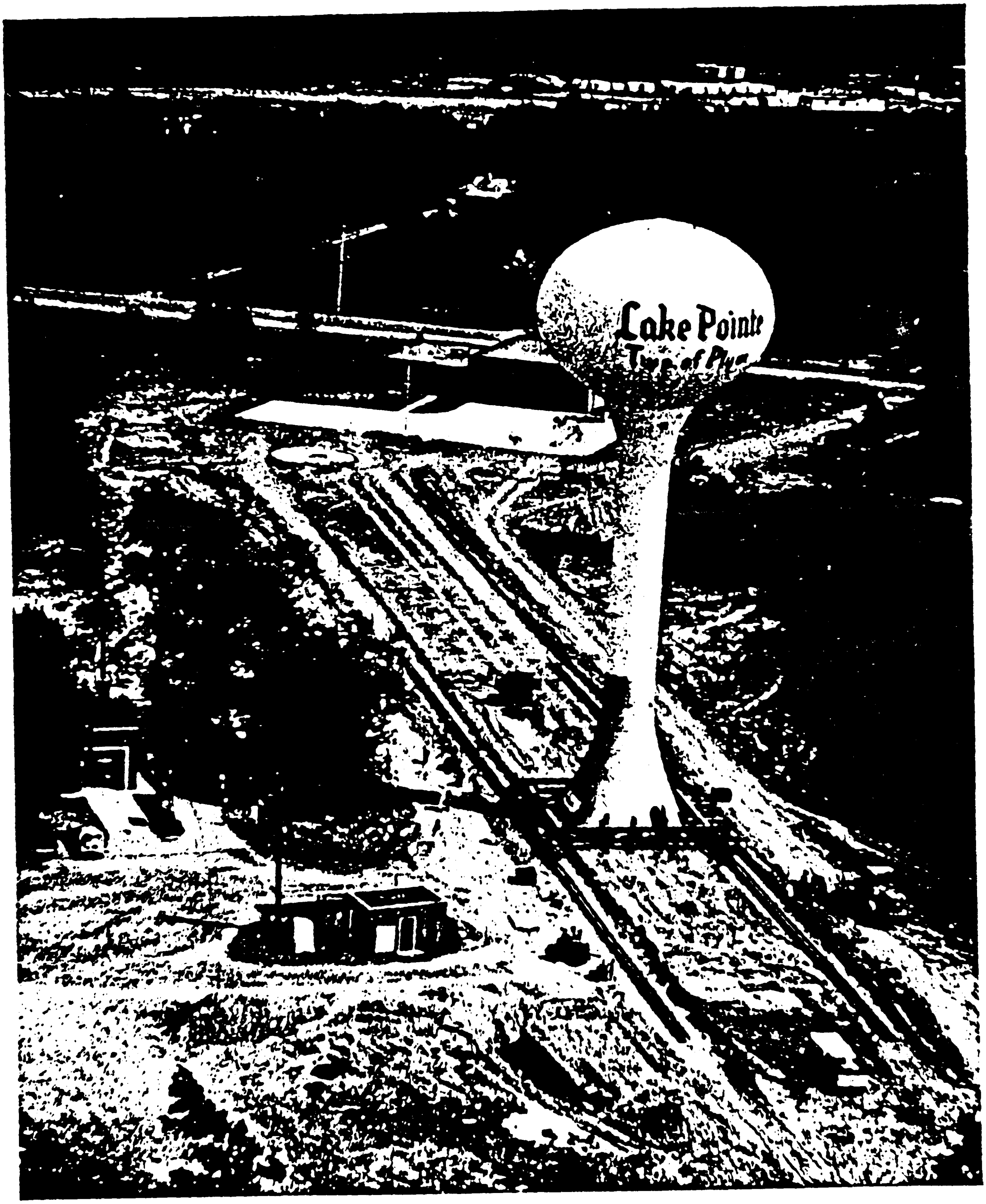
K. F. Adair

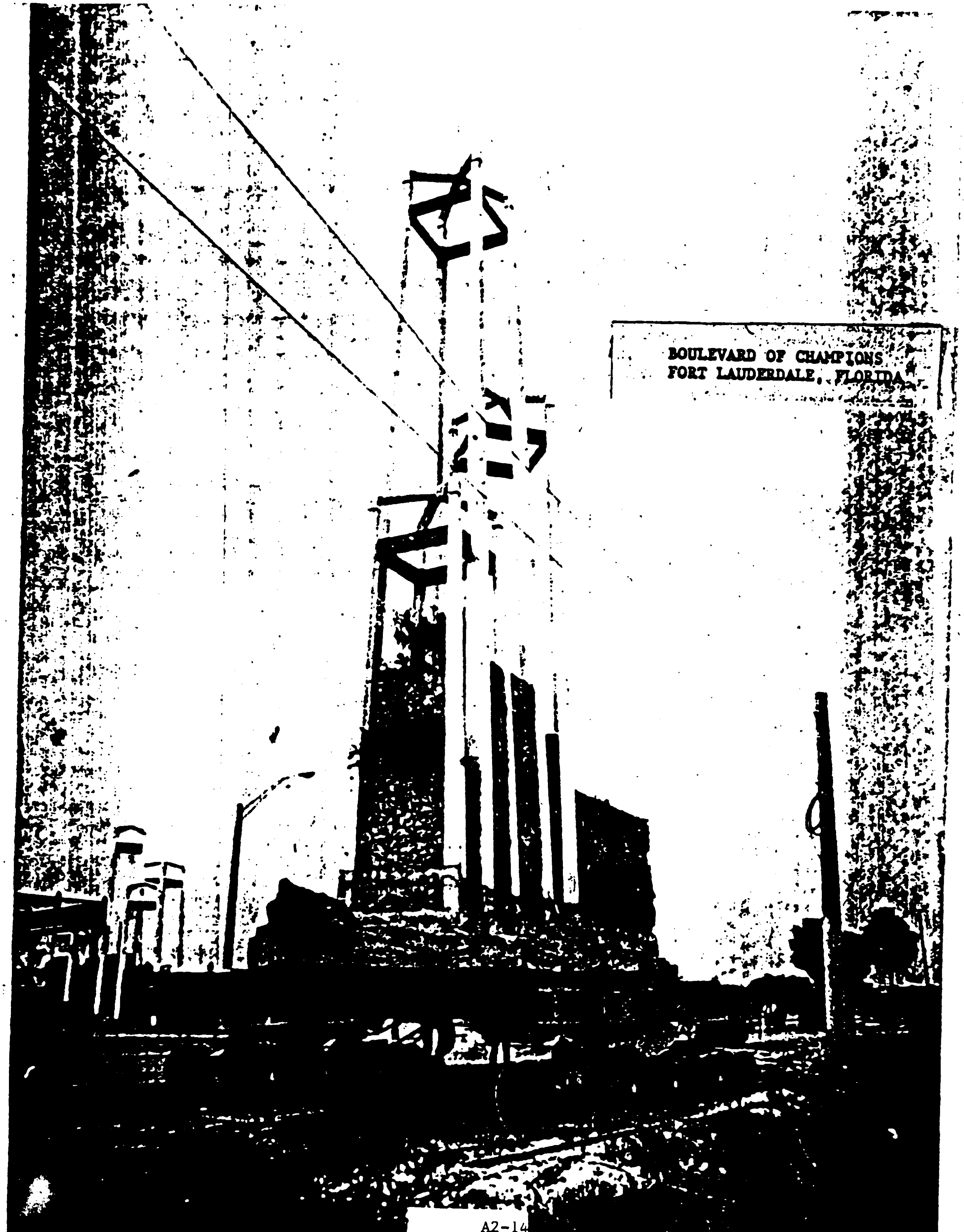
K. F. ADAIR

KFA;mm

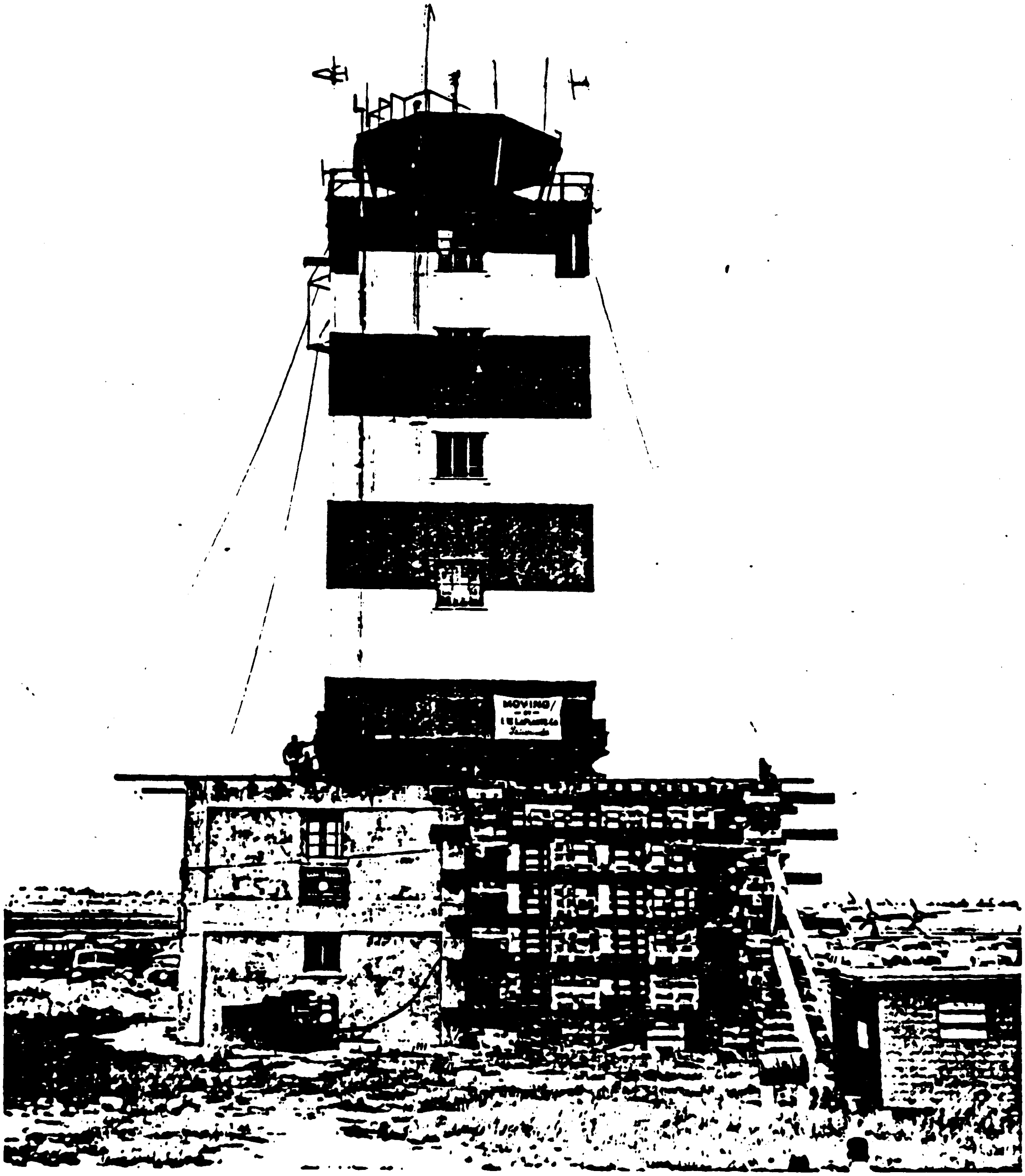
BUILDING MOVING • RAISING • SHORING • UNDERPINNING • FACTORY RECONDITIONING • BRIDGES RAISED AND MOVE

WATER TOWERS MOVED • ROOFS RAISED AND LOWERED • SUBMARINES MOVED


Lake Pointe



BOULEVARD OF CHAMPIONS
FORT LAUDERDALE, FLORIDA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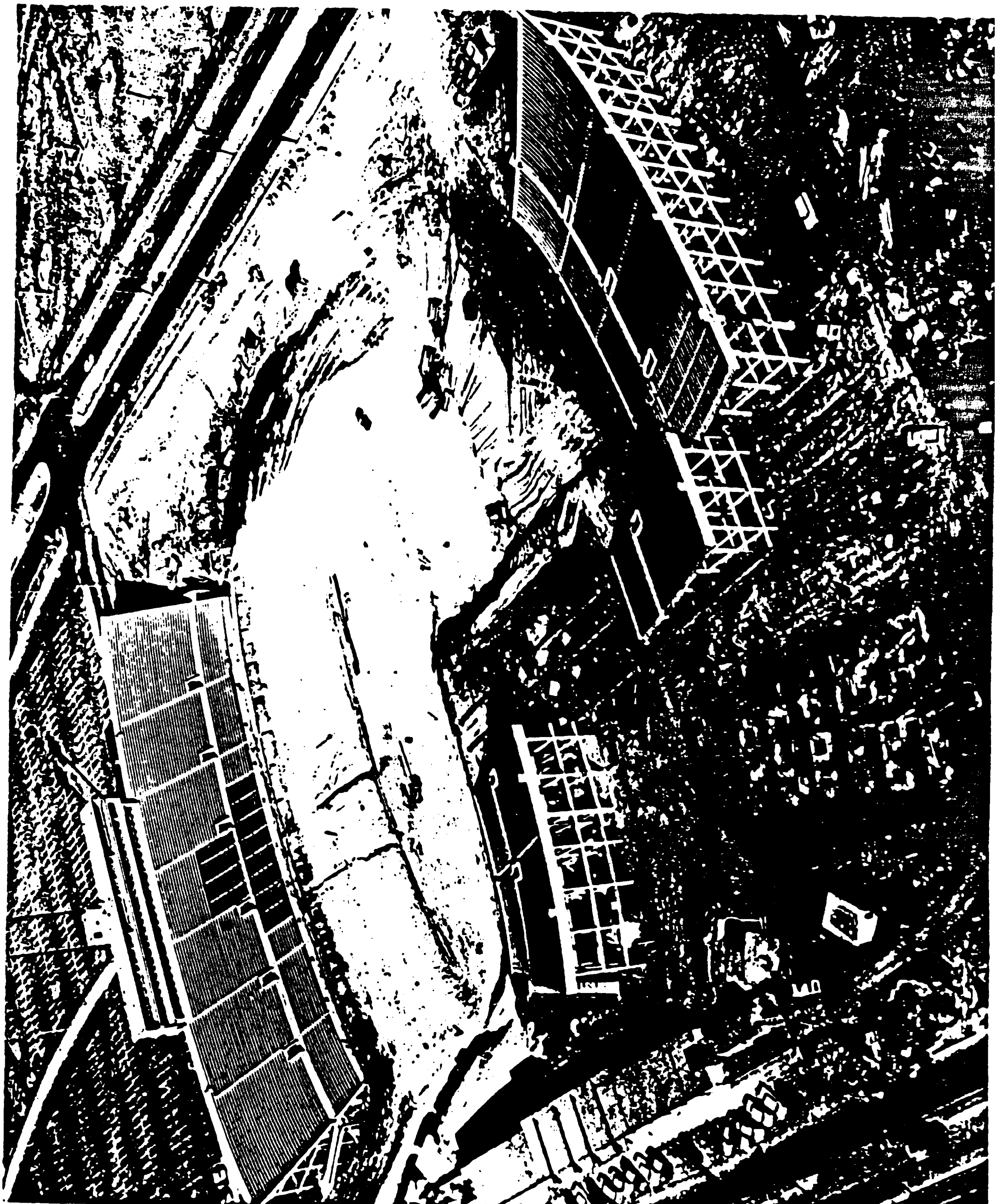


LaPLANT-ADAIR CO. • *Contractors and Moving Engineers*

1200 WEST INDUSTRIAL AVENUE
BOYNTON BEACH, FLORIDA ~~33435~~ 33426
PHONE (305) 737-8188

March 10, 1988

Mr. Tom Chisholm, Engineer
CENEDPL-C
Corp. of Engineers
424 Trapelo Road
Waltham, Massachusetts 92254

Dear Mr. Chisholm:

In our study regarding the relocation of a lighthouse in Massachusetts (size 18'wide x 65' high), we were hampered in not having full information regarding construction details, land conditions, location, etc.

However, working backwards, we came up with the idea that the walls at the base must be 4' thick with a spiral stairway about 3' wide, which leaves us with approximately 5680 pounds per square foot of wall, which is well within the soil capacities and bearing capacities of the masonry.

Considering the above, we believe your budget for the moving only should be \$400,000 to \$500,000.

In the event you would like a guaranteed figure, we will furnish same for the cost of an inspection survey as quoted in our letter of February 10, 1988, which is \$500.00 per day plus all travel expenses portal-to-portal.

Respectfully submitted,

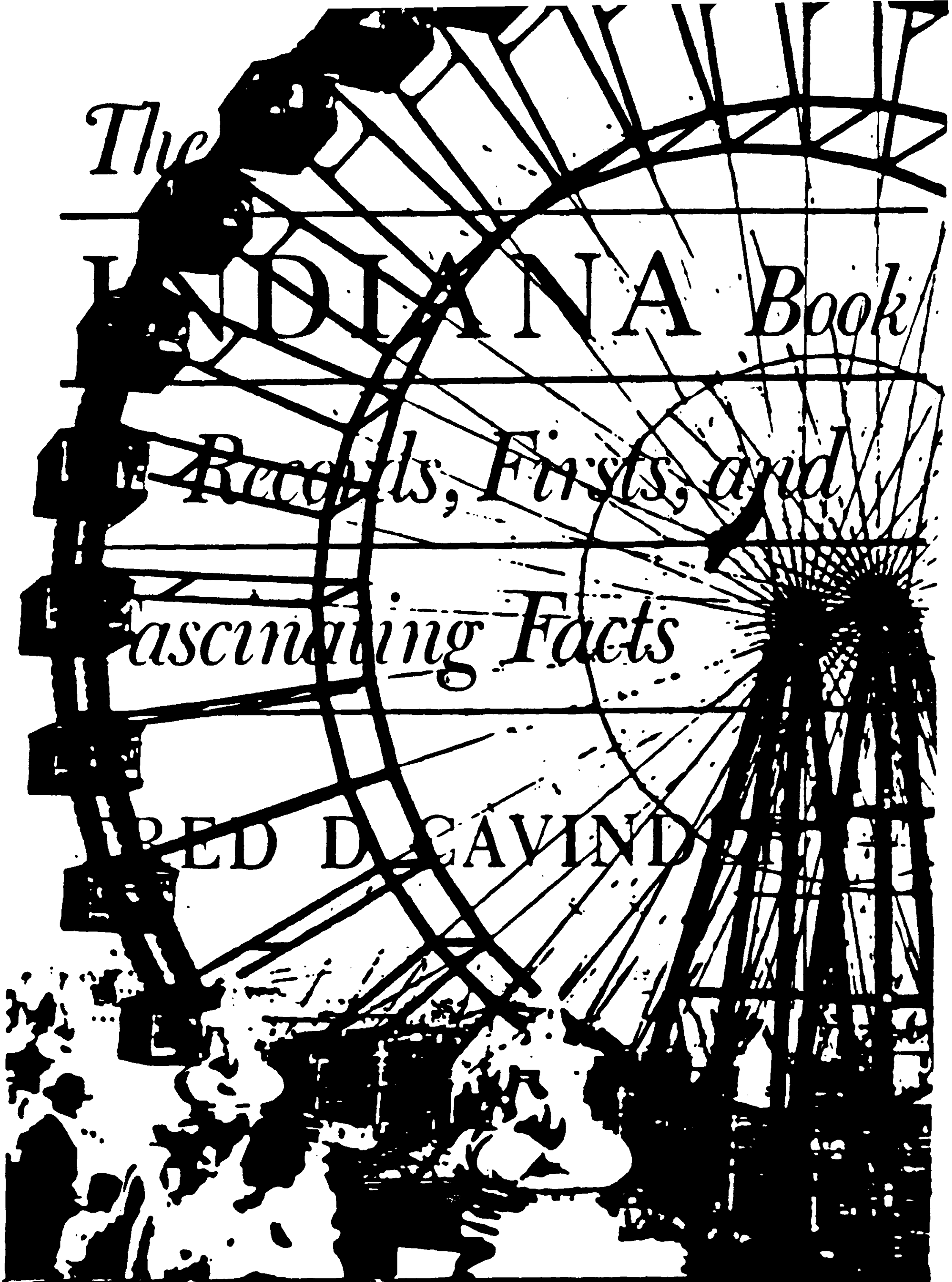
LaPLANT-ADAIR CO.

K F Adair mm

K. F. ADAIR

KFA;mm

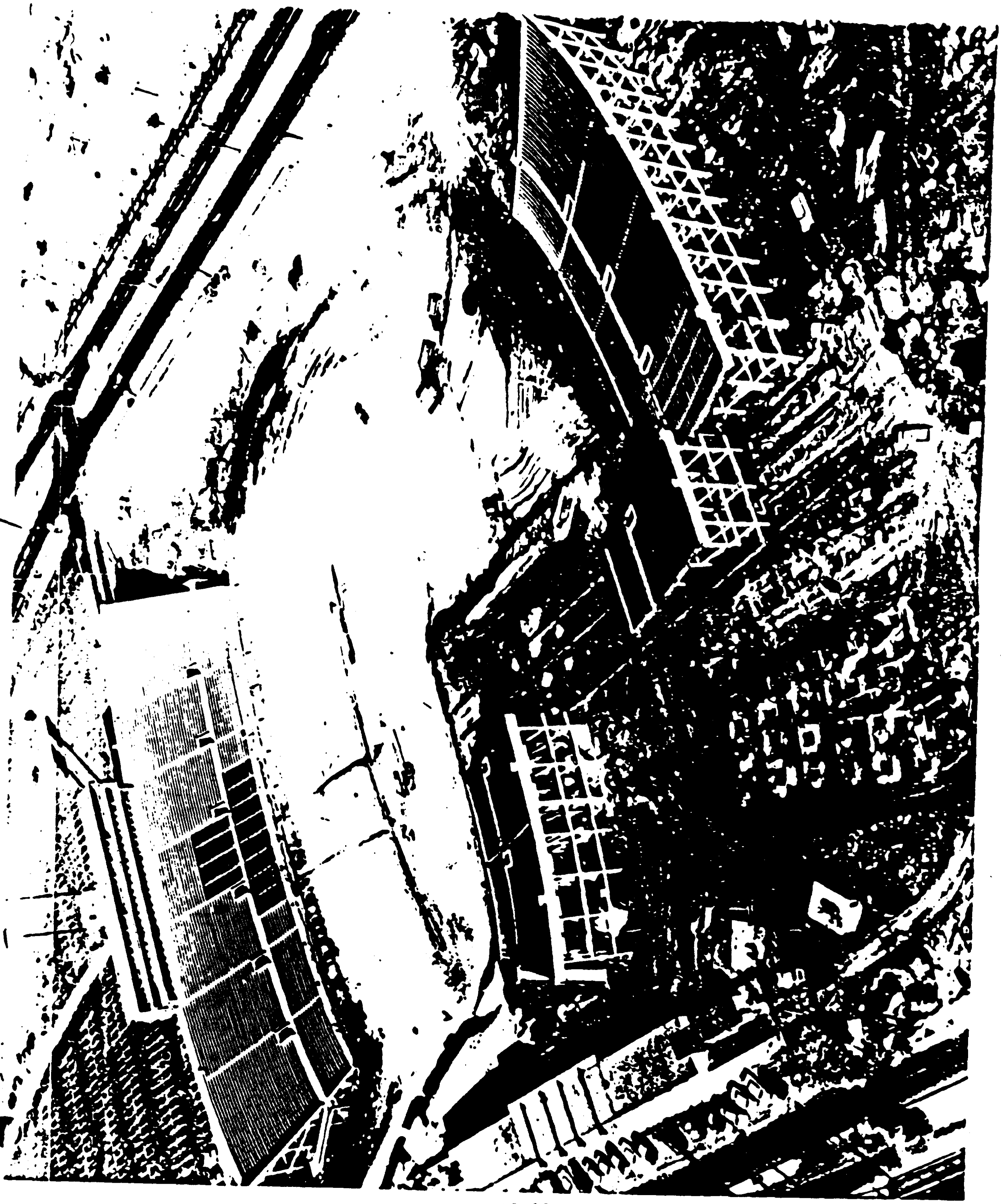
BUILDING MOVING • RAISING • SHORING • UNDERPINNING • FACTORY RECONDITIONING • BRIDGES RAISED AND MOV
WATER TOWERS MOVED • ROOFS RAISED AND LOWERED • SUBMARINES MOVED

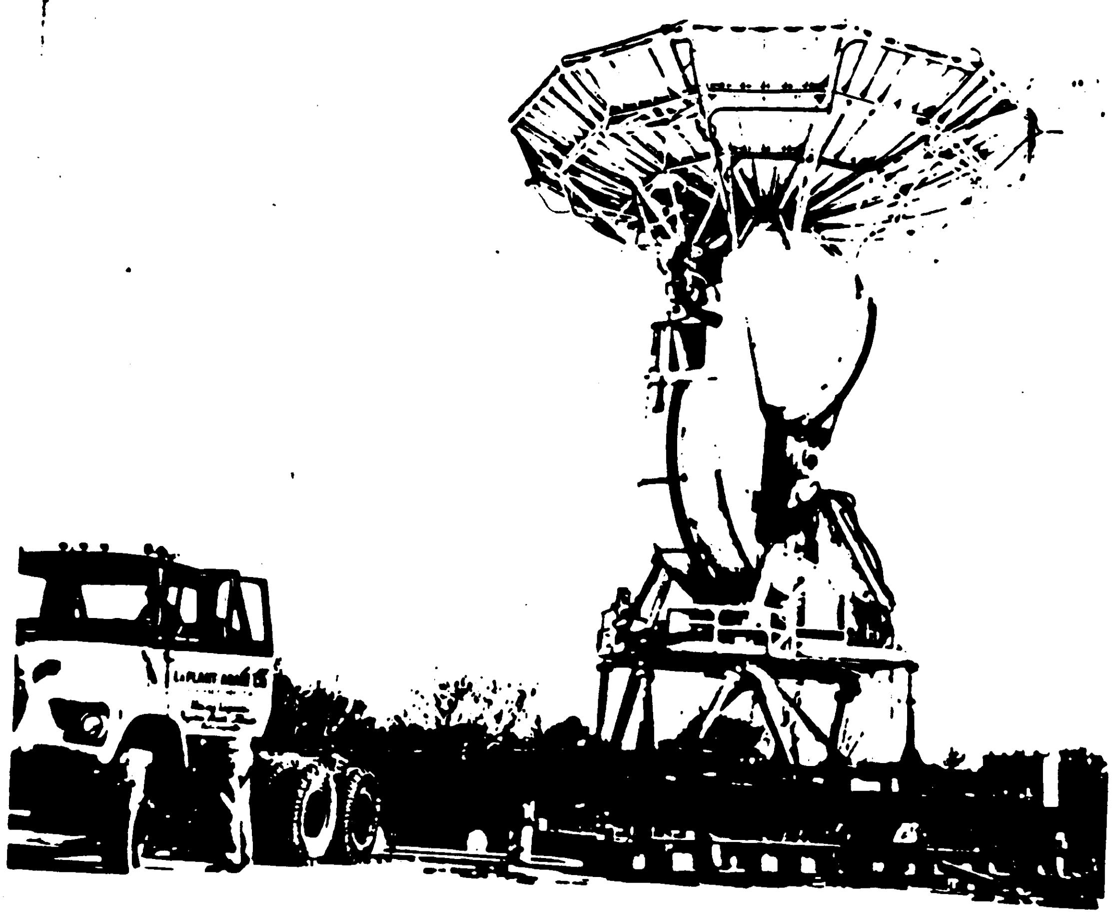


The ***first company to move a water tower,*** **still containing the water,** ***and to elevate a bridge without disrupting traffic*** was the LaPlante-Adair Company of Indianapolis. The water tower, containing 160,000 gallons, was moved in 1957 at the Ford plant in Atlanta, Ga. The 1,500-foot bridge at Lincolnton, Ga., was raised 17 feet in 1951 to allow for a higher dam downstream. The bridge weighed 4,000 tons. In 1964 the same Indianapolis-based firm *moved a German submarine* from Lake Michigan across the Outer Drive to the Museum of Science and Industry in Chicago in nine hours while crowds of up to 15,000 persons watched. The firm later moved from Indianapolis to Florida.

THIS IS THE FIRST ELEVATED TANK OF THIS TYPE TB BE MOVED.

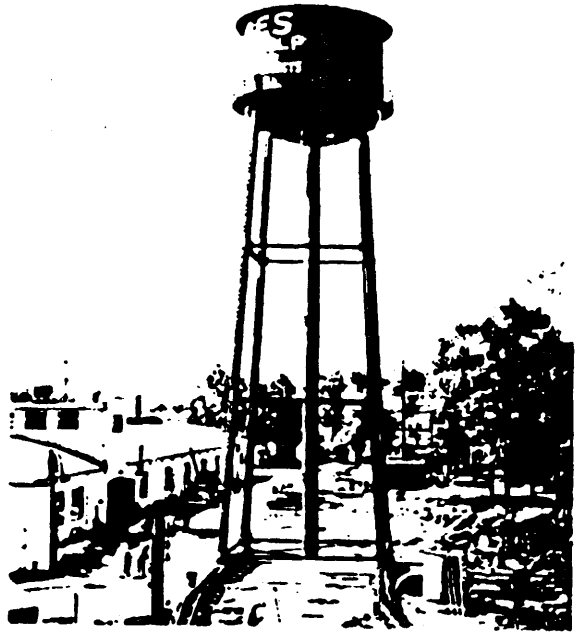
Orgler

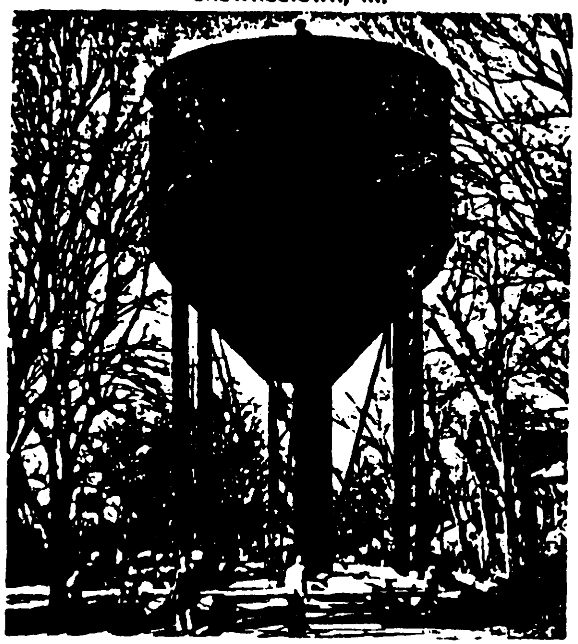


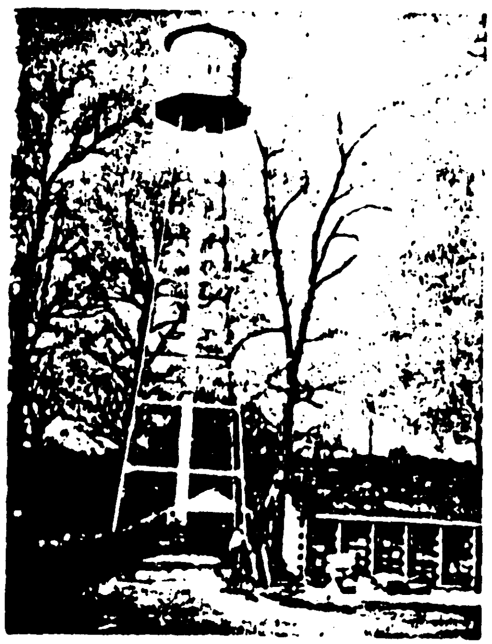


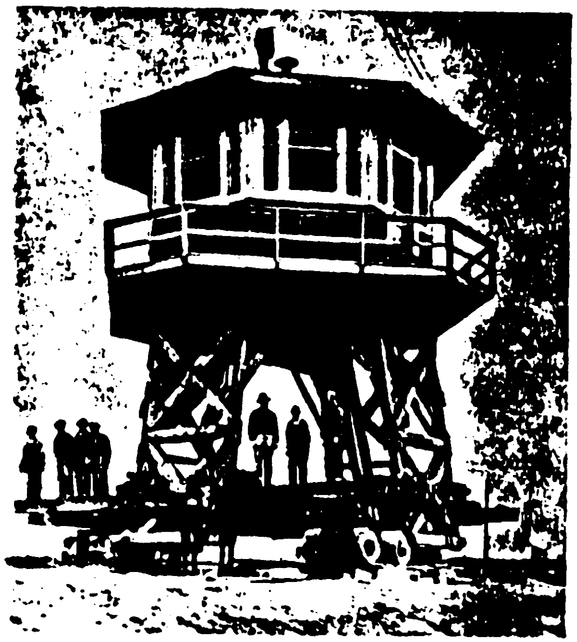

Entire town moved, including water tower and grain elevator
Shawneetown, Ill.


McCall Corporation
Dayton, Ohio


Mapes Molded Pulp Products
Griffith, Ind.

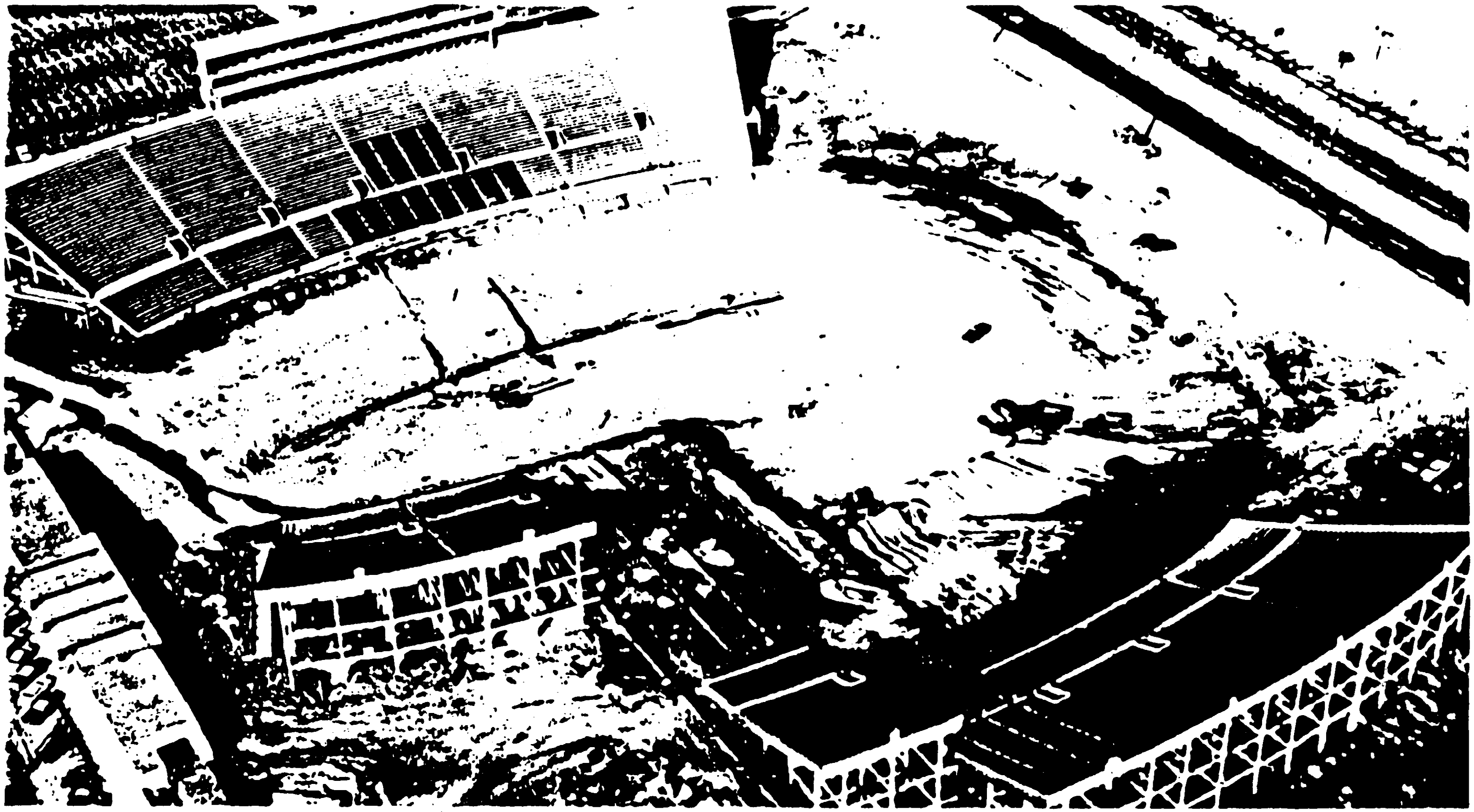

City Water Dept.
Glasgow, Mo.


Bull Shoals Dam
Bull Shoals, Ark.


Como Internment Camp
Como, Miss.

LaPLANT-ADAIR CO.

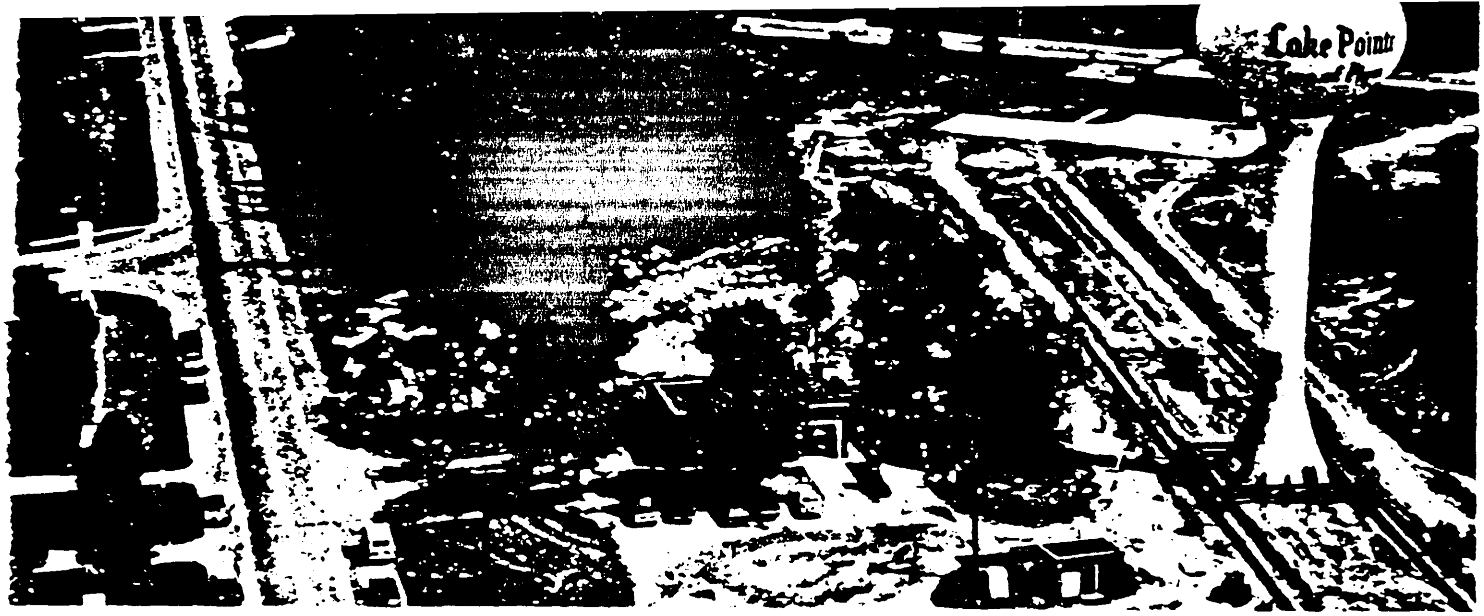
INDIANAPOLIS — MIAMI



Texas Tech Stadium, Lubbock, Tex., 2,620 ton stadium moved 225 ft. for stadium expansion

Moving - Raising - Shoring - Underpinning - Towers
Stacks - Bridges - Ships - Entire Towns Relocated

ALL PHOTOS DEPICT WORK PERFORMED BY THIS FIRM IN THE UNITED STATES AND CANADA —— WE FURNISH SURETY BONDS —— INSURANCE



Looking east along Schoolcraft Rd., the water tower is seen about a third of the way to its new site, a 30 ft. diameter of 8 ft. deep reinforced concrete with 18 in. thick walls. Subcontractor for the base was Harold Bjornstadt Const. Co., Troy.

150 ton tank moved in 3 days

Plymouth — In building the Pyramids the Egyptians moved huge granite blocks by placing rollers under them and hitching up a team of workers. A modern application of this concept was applied in Plymouth Township when it became time to move a 400,000 gal. water tower near Schoolcraft and Wilcox roads.

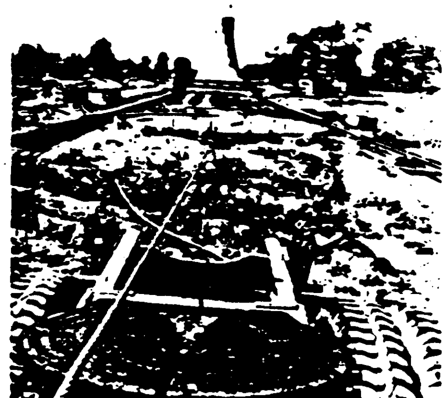
Due to the relocation of M-14, the tower had to be repositioned unto a new base some 500 ft. from its original site. Consulting engineering for the project was handled by Herald F. Hamill, PE, RLS, of Brender-Hamill & Assoc. Inc., headquartered here, and a $150,000 contract for the project was let to Ministrelli Const. Co. of Novi.

The actual moving of the tower was handled by a subcontractor, LaPlant-Adair Co. of West Palm Beach, Fla. The tower was jacked up from its old base and a platform consisting of 12 in. I-beams, three layers thick and approximately 60 ft. square, was constructed underneath it for the move.

At the new site, subcontractor Harold Bjornstadt Const. Co., Troy, built a new base for the tower of 8 ft. deep reinforced concrete, 30 ft. in diameter, with 18 in. thick walls.

Four lengths of rails were laid for the move, two to each side of the platform, with a measurement of 50 ft. spanning the center of each set of rails. The platform and tower was jacked up and the first section of the railroad was built underneath it with rollers spanning the distance between the two rails in each set.

Instead of a team of hard muscled Egyptians, the winch off a Ford 900 truck was used to move the tower



Winching operations were handled with the use of a Ford 900 truck. Travel speed was four feet per minute and three days were needed to move the 400,000 gal. tower the required 500 ft. The distance between the centers of the two sets of tracks is 50 ft.

The platform for moving the water tank consisted of 12 in. I-beams, three layers thick, about 60 ft. square. Rollers were used to move its 150 tons along the rails.

As the tower is moved, tracks from behind it are taken apart and reassembled in front for the move forward. On the left is Mike Adair, project superintendent for the moving subcontractor, LaPlant-Adair of West Palm Beach, Fla.

along the rails at a rate of four feet per minute. As the tower was moved, the tracks behind it were taken apart and reassembled before it. When workers began to run out of rollers in front of the tower platform, the winching operation was halted, allowing rollers to be brought up from the rear and for the forward repositioning of the truck.

It took one week to prepare the water tower for the move and three days to bring it to its new site for installation.

Coordinator for the project for the Michigan Dept. of State Highways and Transportation was William F. Wines. William Duerr was the job superintendent for Ministrelli Const. and Mike Adair was the project superintendent for the moving subcontractor •

Huron Cement appoints Sheila Hoef sales rep.

Detroit — Mrs. Sheila Hoef has been appointed to the position of sales representative in the Detroit Sales District for Huron Cement Southfield.

Mrs. Hoef has been with the firm since 1958, where she began her career in the Pricing Dept. In June, 1970, she was assigned to the Detroit Sales Dept. of the company.

She is a graduate of Dearborn High School and has attended Henry Ford Community College.

July steel bookings

New York, N.Y. — According to reports complied by the American Inst. of Steel Construction Inc., July, 1976 bookings of fabricated steel amounted to 365,000 tons, an increase of 39% over the July, 1975 bookings.

A comparison by type construction to total bookings, July, 1976 versus June, 1976 shows industrial building down to 26% from 44%; utilities building rose to 26% from 16%; commercial building rose to 27% from 24%; bridges no change from 11%; public works rose to 8% from 4%; other rose to 2% from 1%.

Estimated July, 1976 shipments of fabricated steel were 283,000 tons - a decrease of 21% from the June, 1976 estimate. Of the total estimated industry backlog of 4,065,000 tons, about 40% or 1,626,000 tons are scheduled for fabrication within the next four months.

WASHINGTON

FED MONEY GOING SOUTH

The federal government's tax and spending policies are "causing a massive flow of wealth from the Northeast and Midwest to the fast-growing Southern and Western regions of the nation," says a research study produced by a Washington outfit, Government Research Corp., and there's liable to be a strong Congressional reaction to it.

The report says that so-called "donor states" are suffering erosion of their tax base and continued high unemployment even while the rest of the country is recovering slowly, and are facing the threat of cuts in public services that will reduce the quality of life there.

The study compared the federal benefits in the form of defense contracts, public works projects and Social Security payments with the number of tax dollars states sent to Washington. Those states in the sun belt in the West and South were enjoying the greatest population gains, less unemployment and improved per capita income levels. The loser states in the Northeast and Midwest had stagnant populations, severe to moderate unemployment, and by far the greater state and local tax burdens.

"Inequities are almost entirely accidental," the report noted, due to climatic and geographic factors for the most part, but the inequities are real, and are triggering a clamor from Eastern and Midwestern legislators to change federal policies to adjust the balance of payments. Among these are Rep. Michael J. Harrington (D.-Mass.), who is considering a lawsuit against the Economic Development Adm. for channeling money rather evenly across the states instead of concentrating it in areas where high unemployment and business failures indicate the greater need. One contradiction: the biggest beneficiary of federal funds was the District of Columbia, which received \$7.67 for each dollar in federal taxes collected there.

GAS TAX PREDICTIONS

Higher state gas taxes and motor vehicle fees, but no early change in federal auto taxes, were foreseen by two HUFSAM spokesmen in recent days. HUF President Peter Koltnow told an industry group here that popular support for user pay-as-you-go taxes was encouraging, since fuel and operating costs are certain to go up in the years ahead. HUFSAM's PR Director Jack Martin reported at a Bismarck meeting this month that two states - Idaho & Kansas - have added 1¢ to their gas tax, while boosts were still being debated in 11 others. Minnesota Good Roads leader Bob Johnson said his state had added \$147.5 million in new funding since 1975 - 2¢ in new gas taxes and \$50 million in bridge replacement funds. However, a chilling comment from Texas was that if that state relied solely on the motor fuel tax for operating costs in the next two decades, it would need a 1¢ per gallon increase each year for the entire 20 years.

Koltnow told an IBTTA committee meeting that motor travel will increase 25% in the next 10 years despite the fuel shortage, but the future of long-distance vacation travel is still uncertain. Family transportation has cost about 12% of a family's budget in recent years, but this is sure to go up, even though people are keeping their cars longer. He also predicted a greater need for emergency road services as a result of more old cars remaining on the road.

NRC REVIEWS NUC POWER

The Nuclear Regulatory Commission has declared a moratorium on licenses for new nuclear power plants until it has completed a study of possible environmental dangers of reprocessing nuclear reactor fuel and handling radioactive wastes. This study will be completed sometime this fall. The decision followed a July court decision that NRC had not given enough consideration to these issues when licensing plants in Vermont and Michigan. Construction of both has been stopped pending investigation by a licensing board. NRC may decide to review the licenses of all 59 nuclear plants now operating in the U.S. after completion of its study and development of new guidelines for licensing.

SLIGHTEMS

HUD is weighing a plan to scrap its multi-billion dollar housing subsidy program in favor of a national block grant program, a sort of "housing revenue-sharing plan." It would cut miles of municipal red tape from lengthy application processes. Once proposed by Democrats in 1973, it could be used to spike expected criticism from campaigner Jimmy Carter.

Labor Secretary Usery has promised open shop contractors he will reconstitute the Wage Appeals Board to hear complaints re Davis-Bacon •

CAPE HATTERAS LIGHTHOUSE

EVENING CITIZEN
LACONIA, NH
D. 8,046

SEPT 23 1986

Debate Swirls Around Threatened Lighthouse

By TOM MINEHART
AP Writer

BUXTON, N.C. — At the foot of the 116-year-old Cape Hatteras Lighthouse, pounding waves wash away 11 feet of beach a year. Just as unrelenting is the debate over how to save the spiral-striped symbol of the wild North Carolina coast.

The U.S. Army Corps of Engineers plans to begin building a revetment and seawall around the 208-foot tower as early as January, anticipating it will become an island as the Outer Banks shoreline recedes over the next 50 years.

But that $5.6 million plan has stopped neither the people trying to build up the beach with artificial seaweed nor those who want to move the nation's tallest lighthouse inland.

"As soon as they build the wall it's going to seal its fate," said Orrin Pilkey, a professor of geology at Duke University and a member of the Move the Lighthouse Committee. "Once it moves offshore, it's doomed."

Pilkey said the seawall and the revetment, an underground structure, would not stand up to storms, adding that seawalls actually hasten erosion.

"The only way to save the lighthouse is to move it," Pilkey said.

"That's utterly ridiculous," said Hugh Morton, acting chairman of the Save the Lighthouse Committee. "There have been cracks discovered in the lighthouse ... and it extends more than 50 feet below the ground."

Morton's group wants to keep the lighthouse where it is, checking the beach erosion with sand-catching synthetic "seaweed" rather than a seawall.

In 1982, the committee spent about $165,000 to place 5,000 units of artificial seaweed around the beach to settle the water-borne sand into bars. Another installation costing $91,000 is planned soon. The sandbag-anchored units of five-foot-long fabric strips have already filled a deep lagoon to the south of the lighthouse that could have been the greatest threat if a storm came from that direction, he said.

The seaweed plan, he argued, "could build enough beach to put (the University of North Carolina's) Kenan Stadium and Charlotte Motor Speedway out in front."

But officials of the National Park Service, which manages the lighthouse as part of the Cape Hatteras National Seashore, say it can't be proved that the artificial seaweed is doing any good.

"It was uncertain exactly what could be attributed to the product," said Kent Turner, the park service's specialist on the lighthouse beach. "There was some ... buildup along a pretty wide band of beach after the product went in."

Even so, the park service has accepted the Corps of Engineers' recommendation for the seawall and revetment. All that's needed are the final specifications and approval of funding legislation pending in Congress.

David Fischetti, an engineer who heads the Move the Lighthouse Committee, said neither the corps nor the park service gave enough consideration to his group's idea.

Move the Lighthouse estimated in 1980 that it would cost $2.75 million to cut through the lighthouse at its base, lift the 2,600-ton structure onto a concrete-and-steel track and move it about half a mile southwest to an area that would be stable for at least 200 years.

"So many projects have been done around the world that were much more difficult than this," Fischetti said. Czech engineers in 1975 spent $15.3 million to move a 12,000-ton cathedral 800 yards to make way for a coal mine, and in 1967, Italian engineers moved the 300,000-ton Egyptian temples of Abu Simbel to make way for rising Nile waters behind the Aswan Dam.

Moving the lighthouse probably would cost much more than Fischetti thinks, say officials of the corps and the park service, noting that it would have to cross a marsh.

"You can get into very costly structures just to build the roadway," said Tom Jarrett, chief coastal engineer for the corps' Wilmington branch.

The National Aeronautics and Space Administration, which has vehicles that move massive rockets, advised the park service in the late 1970s that moving the lighthouse would cost many times what Fischetti estimated, said Jay Gogue, former regional chief scientist for the park service and now a researcher at Clemson University.

Trying to move the lighthouse would not only threaten to destroy it, it would also change its historical significance and require costly changes on navigation charts, he said.

Jarrett disputed Pilkey's contention that the seawall-revetment structure could not withstand years of storms.

"We've done extensive testing under very severe conditions," he said. "It's a very substantial structure. The massive concrete wall reflects waves, and underneath there's a large, extensive rubble mat that extends 100 feet out in front of the seawall — these are big stones. It's designed for a future shoreline 100 years from now, when the floor will be 10 to 12 feet below the existing ground."

But Fischetti said the park service should consider the asthetic effects of a tall wall around the lighthouse, as well as the boost to tourism that could come from the sheer spectacle of moving the lighthouse.

"It would capture the imagination of a lot of people around the country."

APPENDIX 3

BIBLIOGRAPHY